2006-09

A study on improving United States Air Force space systems engineering and acquisition

Stahr, Jeremiah B.

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/2649

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

A STUDY ON IMPROVING UNITED STATES AIR FORCE SPACE SYSTEMS ENGINEERING AND ACQUISITION

by

Jeremiah B. Stahr

September 2006

Thesis Advisor: Thomas V. Huynh
Associate Advisor: Christopher E. Forseth

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2006	**3. REPORT TYPE AND DATES COVERED** Master's Thesis

4. TITLE AND SUBTITLE: A Study on Improving United States Air Force Space Systems Engineering and Acquisition

5. FUNDING NUMBERS

6. AUTHOR(S) Captain Jeremiah B. Stahr, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (maximum 200 words)

Systems engineering is a vital element of systems acquisition, and yet, as a result of previous Department of Defense (DoD) and United States Air Force (USAF) policies and practices, many government systems engineers today lack the systems engineering/management skills required to successfully execute national security space programs. The purpose of this thesis is to study and understand common issues that have impacted the ability of the USAF to cost-effectively acquire satellite systems. The research performed here involves an analysis of the differences between the traditional DoD systems acquisition and the national security space systems acquisition processes and an investigation of previous national efforts to improve these processes. The analysis results, together with the findings from a review of successful and struggling space programs, are then used to discover trends that aid in the formulation of the recommendations in this thesis. Specifically, to improve USAF systems engineering management skills and thereby improve the national security space systems acquisition process, the role of the government systems engineer should be defined as one of risk management, and the government systems engineers should be trained, equipped, and tracked in order to efficiently perform systems engineering in support of the space systems acquisition process. Finally, the research findings will provide a foundation for future researchers to expand upon the recommendations and make steady progress toward improving DoD and USAF space systems engineering expertise.

14. SUBJECT TERMS
Systems Engineering, Space Systems Engineering, Systems Acquisition, Space Systems Acquisition

15. NUMBER OF PAGES 107

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited.

A STUDY ON IMPROVING UNITED STATES AIR FORCE SPACE SYSTEMS ENGINEERING AND ACQUISITION

Jeremiah B. Stahr
Captain, United States Air Force
B. S., United States Air Force Academy, 1999

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS ENGINEERING MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
September 2006

Author: Jeremiah B. Stahr

Approved by: Dr. Thomas V. Huynh
Thesis Advisor, Department of Systems Engineering

Lieutenant Colonel Christopher E. Forseth, USAF
Associate Advisor

Dr. David H. Olwell
Chairman, Department of Systems Engineering

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Systems engineering is a vital element of systems acquisition, and yet, as a result of previous Department of Defense (DoD) and United States Air Force (USAF) policies and practices, many government systems engineers today lack the systems engineering/management skills required to successfully execute national security space programs. The purpose of this thesis is to study and understand common issues that have impacted the ability of the USAF to cost-effectively acquire satellite systems. The research performed here involves an analysis of the differences between the traditional DoD systems acquisition and the national security space systems acquisition processes and an investigation of previous national efforts to improve these processes. The analysis results, together with the findings from a review of successful and struggling space programs, are then used to discover trends that aid in the formulation of the recommendations in this thesis. Specifically, to improve USAF systems engineering management skills and thereby improve the national security space systems acquisition process, the role of the government systems engineer should be defined as one of risk management, and the government systems engineers should be trained, equipped, and tracked in order to efficiently perform systems engineering in support of the space systems acquisition process. Finally, the research findings will provide a foundation for future researchers to expand upon the recommendations and make steady progress toward improving DoD and USAF space systems engineering expertise.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ABBREVIATIONS/SYMBOLS

AEHF	Advanced Extremely High Frequency
AFCEA	Armed Forces Communications and Electronics Association
AFPEO	Air Force Program Executive Officer
AFPEO/SP	Air Force Program Executive Officer for Space
AFSPC	Air Force Space Command
ATL	Acquisition, Technology, & Logistics
CAE	Component Acquisition Executive
CDD	Capabilities Design Document
CDR	Critical Design Review
CIA	Central Intelligence Agency
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
COTS	Commercial-Off-the-Shelf
CPD	Capabilities Production Document
DAPA	Defense Acquisition Performance Assessment
DARPA	Defense Advanced Research Projects Agency
DAU	Defense Acquisition University
DMSP	Defense Meteorological Satellite Program
DNRO	Director, National Reconnaissance Office
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DSB	Defense Science Board
DSCS	Defense Satellite Communication System
DSP	Defense Support Program
EPs	Emergency Procedures
FFRDC	Federally Funded Research and Development Center
FIA	Future Imagery Architecture
FOC	Full Operational Capability
GAO	Government Accountability Office
GBS	Global Broadcast Service
GEO	Geosynchronous Earth Orbit
GPS	Global Positioning System
HEO	Highly Elliptical Orbit
IC	Intelligence Community
ICBM	Intercontinental Ballistic Missile
ICD	Interim Capabilities Document
INCOSE	International Council on Systems Engineering
IOC	Initial Operational Capability
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Council
KDP	Key Decision Point

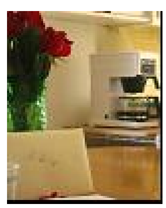
LAAFB	Los Angeles Air Force Base
LRIP	Low Rate Initial Production
LtGen	Lieutenant General
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MFP	Major Force Program
MajGen	Major General
MUOS	Mobile User Objective System
N-POESS	National Polar-orbiting Operational Environmental Satellite System
NOAA	National Oceanic and Atmospheric Administration
NASA	National Aeronautics and Space Administration
NDIA	National Defense Industrial Association
NRO	National Reconnaissance Office
NSS	National Security Space
NSSAP	National Security Space Acquisition Policy
ONIR	Overhead Non-Imaging Infrared
PDR	Preliminary Design Review
PEO	Program Executive Officer
PM	Program Manager
POES	Polar Operational Environmental Satellites
SAMOS	Satellite and Missile Observation System
SBR	Space Based Radar (also Space Radar)
SBIRS-High	Space Based Infrared System – High
SDD	System Development and Demonstration
SDR	System Design Review
SE	Systems Engineer(ing)
SecAF	Secretary of the Air Force
SETA	Systems Engineering and Technical Assistance
SMC	Space and Missile Systems Center
SPD/PM	System Program Director/Program Manager
SR	Space Radar (also Space Based Radar)
SRR	System Requirements Review
STSS	Space Tracking and Surveillance System
TEMP	Test and Evaluation Master Plan
TSPR	Total System Performance Responsibility
U.S.	United States
U.S.C.	United States Code
USA	United States Army
USAF	United States Air Force
USecAF	Under Secretary of the Air Force
USecDef	Under Secretary of Defense
USecDef(ATL)	Under Secretary of Defense (Acquisition, Technology & Logistics)
USN	United States Navy
WGS	Wideband Gapfiller Satellites

ACKNOWLEDGMENTS

Z Y X W V U T S R Q P O N M L K J I H G F E D C B A...

I dedicate this thesis to the memory of my grandfather. Pap was the first person to teach me that there are always more ways than one of looking at something. Who says the alphabet needs to start at the letter ‘A’? If you’re sitting on the right side of the classroom, why can’t the alphabet start on the right side of the room with the letter ‘Z’? Thank you for showing me how to be a good man and for showing me how to care about doing a good job. More importantly, thank you for being a good man and always putting family first.

The countless hours of research, writing and revising are dedicated to my beautiful wife Megan and our two beautiful daughters Mazie and Jamie. They paid the price of my time more than anyone else and now we’re all a year older. I’ve missed countless memories and I can only hope that one day they will forgive the lost time and understand why daddy had to do homework instead of going to the park or playing Candyland. Thank you, Megan, for your support and understanding. Without you, I simply don’t know how to be a good husband, father, officer.



I also want to thank Major General Don Hard (USAF, retired) for taking the time to discuss my research findings and to offer his wisdom to a young officer. Finally, I want to offer a most sincere thanks to my advisor, Dr. Tom Huynh, for his assistance throughout this process; my supervisors, Lt Col Tom Becht and Ms. Michel Guthrie-Vaccaro, for allowing me a flexible work schedule; and my numerous co-workers for assisting me with moral support and sometimes picking up my slack. This work would not have been possible without your support, and I could not have amassed this effort without your expertise. Lt Col Forseth – thank you, sir, for showing me the meaning of ‘professional courage’ and for recognizing it when you saw it. Where necessary, I have paraphrased the views and opinions of others. I assure all readers that errors of substance are not the fault of these contributors, but rather are my own fault.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. BACKGROUND

The United States Air Force (USAF) and Department of Defense (DoD) space systems acquisition process has increasingly become synonymous with exorbitant cost overruns, substantial schedule delays, and sometimes outright program failure. At a recent National Defense Industrial Association conference, Senator Wayne Allard (Republican from Colorado and member of the Senate Appropriations Committee) quoted the Defense Science Board (DSB) and the Government Accountability Office (GAO) as having significant concerns over issues pertaining to the cost and performance of our national security space systems (Allard, 2005). Additionally, the DSB and GAO have discovered that it is the acquisition process that is the cause of these problems. Cost and performance issues are not new, and many have been addressed repeatedly in the past by numerous Congressional panels and commissions.

Because the environmental and orbital considerations in dealing with operations outside of the Earth environment are unnaturally foreign as compared to most human endeavors, the acquisition of space systems is inherently a more complex and time consuming process than that of traditional Earth-bound systems. Consequently, there are bound to be difficulties in estimating the required cost and schedule to meet a certain performance/capability. The acquisition of satellite systems is difficult enough – so the process by which these systems are developed must not be allowed to become the most significant burden. Senator Allard has stated, “our nation’s dominance in space is being challenged not so much from outside this country but from within. In many respects, we have become our own worst enemy.” He went on to say “we have done everything possible to sabotage our space supremacy” (Allard, 2005). Not only do the acquisition and engineering professionals thus need to deal with the inherently difficult task of developing space systems, but they must also utilize a very complex system to do so. Unfortunately, as many of the Congressional panels and commissions of the last two decades have shown, many of the USAF personnel responsible for systems engineering in support of systems acquisition do not know what their defined role is or how to complete their job well.

One area that needs more attention in the realm of space systems acquisition is systems engineering management expertise. Good systems engineering is a critical component of systems acquisition. Do the USAF systems engineers involved in space systems acquisition know what their role is? Do they have the right skill set to effectively and efficiently perform their systems engineering management responsibilities? As documented in the 2001 Space Commission Report and the 2003 Defense Science Board's Young Panel, the Department of Defense acquisition system has seen the rise and fall of Total System Performance Responsibility (TSPR) as a preferred acquisition approach. Additionally, there has been a noted decrease in systems engineering expertise throughout the 1990's. Recently, the United States Air Force Space Command (AFSPC) has recognized there are career progression issues in space systems acquisition and is currently in the midst of a renewed emphasis on Space Professional Development. This emphasis includes the cadre of space acquisition professionals. Finally, since the very beginning of space systems acquisition, the Department of Defense has relied on the expertise of Federally Funded Research and Development Centers (FFRDC) to support the space systems engineering and acquisition processes. Each of these areas – the use of TSPR, draw-down of systems engineering expertise, career progression, and utilization of FFRDC – has, in its own way, lead to the current posture of United States Air Force space systems engineering and space systems acquisition. Some of these areas have helped, and some of these areas have hindered, the ability of the USAF to properly acquire national security space systems. The issues associated with these areas should be more thoroughly understood in order to better prepare the United States Air Force to design and build the space satellite systems of tomorrow.

B. PURPOSE

This research is intended to provide an understanding of the underlying issues associated with the areas discussed above in order to assist the USAF more effectively and efficiently develop and procure space systems for the Department of Defense. This research will help define the proper role of the government systems engineer within the acquisition process and identify what skills are required of a government systems engineer to successfully conduct systems engineering activities in support of systems

acquisition. The intent of this research is to identify any systemic issues associated with USAF space systems engineering management expertise and how these issues relate to high cost and schedule overruns. The objective of this research is to qualitatively analyze the differences between the traditional USAF systems acquisition and the national security space systems acquisition, as well as previous efforts to improve these acquisition processes, in an effort to provide specific recommendations that can be implemented in an effort to improve USAF systems engineering management skills and thereby improve the USAF national security space systems acquisition process.

C. RESEARCH QUESTIONS

This research attempts to answer this primary question: Are there systemic systems acquisition issues as a result of past DoD and USAF policies and practices that have impacted the ability of the United States Air Force to properly perform systems engineering in support of the acquisition process? Answering this question requires an answer to each of the following specific research questions:

1. Are there common systems engineering policy or process issues that have impacted the skill-set and experience of Air Force personnel to properly support the acquisition of satellite systems?

2. What is the lasting legacy of the Total System Performance Responsibility (TSPR) on the ability of Air Force space systems engineering personnel to support the space systems acquisition process?

3. How significant are the remaining impacts of the 1990's drawdown of systems engineering expertise on the ability of Air Force space systems engineering personnel to support the space systems acquisition process?

4. Are there any impacts of career progression and personnel continuity issues on the ability of Air Force space systems engineering personnel to support the space systems acquisition process?

5. How does the heavy reliance on Federally Funded Research and Development Centers (FFRDC) help or hinder the ability of the United States Air Force to properly design and develop space systems?

It is the hope of this author that the answers to these questions, obtained through researching and analyzing the history of DoD and USAF space systems acquisition and space systems engineering, will lead to and form the basis of recommendations put forth in Chapter V for future improvements in the current posture of USAF space systems engineering.

D. BENEFITS OF STUDY

This study will attempt to provide specific recommendations to the United States Air Force and Department of Defense for increasing the ability of space systems engineering personnel to perform their proper systems engineering role in support of the national security space systems acquisition process.

E. SCOPE

The emphasis of this thesis directly pertains to past and current systemic issues that have impacted the ability of Air Force personnel to understand and properly perform their role of systems engineering in support of space systems acquisition. The work will qualitatively analyze previous and existing policy recommendations in order to determine the lasting legacy on space systems engineering of the Total System Performance Responsibility acquisition methodology, the drawdown of systems engineering expertise in the 1990's, the impact of career progression and personnel continuity concerns, as well as the advantages and disadvantages associated with a heavy reliance on Federally Funded Research and Development Centers. Finally, this thesis will attempt to make specific recommendations to help solve problems resulting from these policies.

F. METHODOLOGY

1. Conduct a literature review of the objectives and skills required for successful systems engineering. Also, conduct review of the relationship between systems engineering as a component of systems acquisition and program management.

2. Review the current Department of Defense policies and guidance for systems engineering and systems acquisition.

3. Review the current National Security Space policies and guidance for systems engineering and systems acquisition.

4. Conduct a literature review of the peculiarities of space systems and compare them to traditional military systems.

5. Conduct an in-depth review of the history of space systems acquisition. In particular, conduct a detailed review of previous Congressional panels, commissions, and reform initiatives to qualitatively investigate the impact these initiatives have had on the ability of United States Air Force personnel to properly use systems engineering in support of systems acquisition.

6. Conduct a brief review of some past United States Air Force space programs, both successful and not-successful to look for trends in acquisition and systems engineering policies.

7. Correlate information and findings resulting from this research to determine specific research findings. Discuss the research findings with a recognized expert in the space systems engineering field in order to corroborate the information and findings.

8. Using the gathered information and research findings, formulate specific recommendations that can help United States Air Force personnel properly know their role and conduct systems engineering in support of Department of Defense space systems acquisition.

G. THESIS ORGANIZATION

The rest of this thesis is organized as follows. Chapter II contains a review of general systems engineering practices and what skills are required to successfully conduct systems engineering. It also provides a description of some of the specific skills required for conducting systems engineering for aircraft and space systems acquisition. This chapter also contains the results of some literature research and delves into the specific Department of Defense and United States Air Force systems engineering and acquisition processes. Finally, it also includes a comparison and contrast of space systems engineering activities for aircraft vs. satellite systems acquisition. The bulk of Chapter III contains a review of DoD and USAF space systems acquisition policy in an attempt to gather some preliminary lessons learned and trend information pertaining to systems engineering expertise in the United States Air Force. The rest of chapter III includes a review of a few past and current space acquisition programs. Chapter IV, ties

the literature review from Chapters II and III to the research questions formulated above to provide the resulting research findings. Chapter IV also provides other significant trends discovered as part of this research and concludes with information gathered through a personal interview in support of these research findings. Chapter V presents an overview of the current status of United States Air Force space systems acquisition and provides recommendations based on the research findings in Chapter IV. Finally, Chapter V includes several suggestions for further study.

II. REVIEW OF SYSTEMS ACQUISITION AND SYSTEMS ENGINEERING

A. INTRODUCTION

Before delving into the issues of Department of Defense and United States Air Force space systems engineering, the terms ‘system’ and ‘systems engineering’ must first be defined. Their definitions can be particularly important to an organization because its organizational culture is defined in part by how it defines its roles and responsibilities (Ancona, Kochan, Scully, Van Maanen, & Westney, 2005). Suffice it to say, there is no common definition of a ‘system’ or ‘systems engineering.’ The INCOSE (International Council on Systems Engineering) website posts Rechtin’s definition of a ‘system.’

> A system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behavior and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected. (Rechtin, 2000)

A system is thus more than the sum of its parts. Furthermore, although INCOSE recognizes no single definition of the term ‘systems engineering,’ the INCOSE website summarizes the term ‘systems engineering’ as follows:

> Systems Engineering is an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholder’s needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system’s entire life cycle. (www.incose.org, 2006)

The INCOSE concept of systems engineering emphasizes an ‘interdisciplinary approach’ that combines the ‘customer and stakeholder’s needs.’ Finally, it states that systems engineering must be completed in a manner that accounts for quality, in addition to cost and schedule performance over the entire life-cycle of the system. These key tenants provide for a holistic approach that incorporates quality, cost, and schedule in addition to meeting the basic needs of the customer.

The Space and Missile Systems Center (SMC) at Los Angeles Air Force Base (LAAFB), the Defense Acquisition University (DAU) at Fort-Belvoir, Virginia, and the National Aeronautics and Space Administration (NASA) have also defined 'system' and 'systems engineering' as they relate to space systems engineering. According to the DAU's *Systems Engineering Fundamentals* text, a system "is an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective (Defense Acquisition University [DAU], 2001), while according to the "SMC Systems Engineering Primer & Handbook," a system "can be thought of as a set of elements that interact with one another in an organized or interrelated fashion toward a common purpose that cannot be achieved by any of the elements alone or by all of the elements without the underlying organization" (Space and Missile Systems Center [SMC], 2005). Though these definitions are different, they both define an integrated product to fulfill some purpose or need. More specifically to the purposes of this research, a military system is defined by SMC as a system "to provide a needed or desired operational capability to the military forces or to support the military forces in achieving or maintaining an operational capability" (SMC, 2005). Military systems can be weapons or support systems. According to the National Security Space Acquisition Policy 03-01 (NSSAP 03-01), "National Security Space is defined as the combined space activities of the DoD and National Intelligence Community (IC)" (Department of Defense [DoD], 2004). By combining the definitions reviewed thus far, a military space system can be defined as a particular type of military system. Military space systems are systems based in, through, or from space that are weapons or support systems to provide a needed operational capability to the military or to support the military. For purposes of this research, the focus will be on the space segment of a military space system, and the term 'satellite' will be used as applicable.

Using these definitions, 'systems engineering' can simply be defined as applying an engineering discipline to a system. According to the SMC Primer, this is a valid statement. "Engineering is the application of science to develop, design, and produce logical and/or physical objects such as buildings, machines, or a computer program to fulfill a desired need or to achieve an objective. To state the obvious then, systems engineering is the engineering of a system – it is the application of science to design a

system. …the ultimate objective is a design for the system. All else is important and useful only to the extent that it contributes to the efficient achievement of that objective" (SMC, 2005). However, according to the DAU's Systems Engineering Fundamentals, systems engineering is not so simple, rather it is a combination of two "significant disciplines" – "the technical knowledge domain in which the systems engineer operates, and systems engineering management" (DAU, 2001). Therefore, "systems engineering is an interdisciplinary engineering management process that evolves and verifies an integrated, life-cycle balanced set of system solutions that satisfy customer needs" (DAU, 2001). The NASA Handbook defines systems engineering in much broader terms than does the SMC Primer. According to NASA, system engineering is "a robust approach to the design, creation, and operation of systems. In simple terms, the approach consists of the identification and qualification of system goals, creation of alternative system design concepts, performance of design trades, selection and implementation of the best design, verification that the design is properly built and integrated, and post-implementation assessment of how well the system meets (or not) the goals" (National Aeronautics and Space Administration [NASA], 1995).

As noted by Ancona, et al., an organization's culture can be impacted by the accepted definition of common terms. Therefore, if a systems engineering process is to be understood and utilized effectively, it must be based on a common mindset by those who use the process and/or its outputs. It is vitally important for the role of the systems engineer to be properly defined within the context of the overall systems acquisition process if it is to be effectively integrated in an acquisition program. Additionally, if the systems engineer is expected to be of assistance in controlling the overall acquisition program's cost, schedule, risk and performance/capability baselines, he or she must be provided with or already have the required skills and tools to perform the defined roles. Otherwise, a critical mismatch of high expectations to limited results will occur.

B. SUCCESSFUL SYSTEMS ENGINEERING

1. Objectives of Successful Systems Engineering

In *Visualizing Program Management,* the authors state "the system engineer/manager – second only to the project manager in responsibility and accountability – is responsible for the technical integrity of the project while meeting the

cost and performance objectives of the project requirements" (Forsberg, Mooz, & Cotterman, 2000). In defining the objective of systems engineering, NASA also emphasizes a large burden of technical responsibility in addition to balancing other programmatic factors: "The objective of systems engineering is to see to it that the system is designed, built, and operated so that it accomplishes its purpose in the most cost-effective way possible, considering performance, cost, schedule, and risk" (NASA, 1995). The SMC Primer focuses more heavily on the technical aspects of systems engineering, stating the systems engineer "is first and foremost responsible that the 'right system' is developed to meet the customer's needs" and "shall ensure that the ultimate system is 'developed right'" (SMC, 2005). Again, there are differing definitions of the roles and responsibilities of systems engineers between NASA and SMC. The difference is particularly important to note because each of these organizations must take care to ensure its personnel are equipped with the necessary skills and tools required to perform their defined roles and responsibilities.

2. Skills Required for Successful Systems Engineering

Many skills are required to be successful at systems engineering. Although there is no single, magical list of required skills, for purposes of this research, the skills can roughly be summarized in the following, not-all-inclusive list (incorporated from Visualizing Program Management, the SMC Primer, and DAU's Systems Engineering Fundamentals).

- Requirements generation/management
- Problem-solving
- Phasing/planning/baseline management
- Integration and test
- Analysis/modeling and simulation
- Risk management
- Interface control
- Understand required technology
- Concept/architecture design

In 2000, Sarah Sheard described the twelve roles of a systems engineer. At the time, INCOSE had not accepted a single definition of a 'systems engineer' or 'systems

engineering,' and Sheard's articles were an attempt to provide a "vocabulary to what people meant when they were talking about systems engineering" (Sheard, 2000). The twelve roles overlap with the skills shown above and include: "requirements owner, system designer, system analyst, validation/verification engineer, logistics/operations engineer, glue among subsystems, customer interface, technical manager, information manager, process engineer, coordinator, and classified ads systems engineer" (Sheard, 2000).

Some of the skills on the list of skills are very specialized tools (e.g., modeling and simulation) that demand the systems engineer first have a solid grounding in the knowledge of his/her discipline (SMC, 2005). Others are more closely related to the "artistic" side of systems engineering (e.g., concept/architecture design). Systems engineering is not simply science applied to design. It is "important to note that in most cases the engineer has no direct way to arrive at the design such as by a set of formulas…instead he or she must create (or invent)," and in most cases, the engineer will be held responsible to balance "such factors as cost, producibility, and the design margin that accounts for uncertainties" (SMC, 2005).

The DAU *Systems Engineering Fundamentals* guide requires a systems engineer to have the proper skills to enforce what it calls a "recursive problem-solving process" applied throughout the entire acquisition process. These skills correspond to the scope and responsibility put forth by the definition and objectives of systems engineering. However, there is an area of potential vagueness in the SMC Primer. The Primer suggests a systems engineer should have the skills to properly balance several factors – including cost – yet, as noted previously, the systems engineer's responsibility is not defined to include these factors. The balance between the defined roles and responsibilities of a systems engineer and the skill-set of the systems engineer can dramatically impact his/her ability to successfully support the acquisition program. This may also impact the expectations and relationship between a systems engineer and a program manager.

3. Relationship of Systems Engineering and Program Management/Acquisitions

According to the Department of Defense Instruction 5000.2, the two fundamental requirements for a program manager are to use an Integrated Product and Process approach (specifically including systems engineering) whenever possible and to utilize and enforce a rigorous systems engineering approach (Department of Defense [DoD], 2003b). This process “is a top-down comprehensive, iterative and recursive problem-solving process, applied sequentially through all stages of development” (DAU, 2001).

There is a balance of responsibility between the systems engineer and the program manager. The program manager is responsible for the success or failure of a program by fulfilling the requirements of the customer, stimulating a positive work environment and generating a positive return on investment (Forsberg, et al). However, the program manager cannot alone complete the activities listed here and absolutely must rely on solid information and input from the systems engineer. “A major part of the system engineer’s role is to provide information that the [program] manager can use to make the right decisions” (NASA, 1995). More specifically, the systems engineer’s responsibility is “to provide the tools, analyses, and technology trades required to help decision-making by balancing the desired user capabilities against the program cost, schedule and risk.” This responsibility of the systems engineer does not change the ultimate responsibility of the course of action from the program manager, but rather shows how inextricably linked these disciplines are and how dependent the program manager is on good systems engineering expertise. Finally, the overall program performance in terms of cost, schedule and risk directly reflects the technical plan and the ability of the systems engineer to execute the technical plan (SMC, 2005).

“There is no ‘typical’ system acquisition” (DAU, 2001). Although there may not be a ‘typical’ system acquisition, and no matter how different space systems acquisition is from general acquisition, systems engineering and systems acquisition are inextricably linked. “The application of systems engineering management coincides with acquisition phasing” (DAU, 2001). As described in *Systems Engineering Fundamentals*, “systems engineering is the technical management component of DoD acquisition management” (DAU, 2001). Therefore, systems engineering, when combined with business

management and contract management, comprises the general framework for a successful acquisition management approach. Supporting the overall systems acquisition, the systems engineering management process contains three integrated activities including "developmental phasing that controls the design process and provides baselines that coordinate design efforts," a process of systems engineering "that provides a structure for solving design problems and tracking requirements flow through the design effort," and "life-cycle integration that involves customers in the design process." These activities help ensure the system will meet the requirements and will be supportable throughout the life-cycle (DAU, 2001).

Though the program manager and systems engineer are different individuals, their jobs and responsibilities are tightly interwoven. The SMC Primer ties the overall program performance, specifically including cost and schedule performance, to the systems engineer's execution of the technical plan. Therefore, the engineering and acquisition framework used by SMC should carefully define the role and responsibility of the systems engineer appropriately and ensure he/she has the required skills and training to properly perform these responsibilities.

C. DEPARTMENT OF DEFENSE SYSTEMS ENGINEERING AND ACQUISITIONS

At the Defense Department level, there is surprisingly little clear direction in terms of systems engineering processes. The lead acquisition policy document, Department of Defense Directive 5000.1 (DoDD 5000.1) and its companion instruction, the Department of Defense Instructive 5000.2 (DoDI 5000.2) contain only four references to systems engineering. Three of these four references are tangential references to a "systems engineering methodology" or a "systems engineering process" within the realms of sustainment, human factors engineering, and environmental, safety, and occupational health (DoD, 2003b). There is very little description of any of these realms. Though the "5000 Series," as this set of documents is commonly referred, are certainly high-level policy documents, the extent of formal direction to acquisition programs in using systems engineering is contained in Enclosure 1 of DoDD 5000.1.

> E1.1.27 <u>Systems Engineering.</u> Acquisition programs shall be managed through the application of a systems engineering approach that optimizes the total system performance and minimizes the total ownership costs. A

> modular, open-systems approach shall be employed, where feasible. (DoD, 2003a)

This reference from Enclosure 1 of DoDD 5000.1 is the only use of the term 'systems engineering' within DoDD 5000.1. There is no explicit definition of a systems engineering process, methodology, or any guidance on how to optimize the opposing goals of total system performance and minimized total ownership costs. Similarly, there is no defining information on employing a "modular, open-systems approach." Such a lack of specific guidance makes it difficult for systems engineers to be able to define their roles appropriately. The Joint Program Management Handbook also acknowledges systems engineering as a critical discipline, but it fails to deliver any specific guidance.

> As with service programs, SE [systems engineering] in joint program management is an essential tool. Interrelationships, e.g., sensor to ground station, munitions to multiple component platforms, can be analyzed by operational research techniques to develop optimal solutions. When combined with analysis of key performance parameters and operational testing, systems engineering can help a joint PM [program manager] effectively limit risk in a very complex undertaking. (DAU, 2004)

The DoDD 5000.1 provides for a Total Systems Approach (documented as the "Defense Acquisition Management Framework" in DoDI 5000.2) to developing and delivering weapon systems, but this Total Systems Approach is specifically *not* the systems engineer's job and the systems engineer is not explicitly discussed as part of this process. "The PM shall be the single point of accountability for accomplishing program objectives for the total life-cycle systems management, including sustainment" (DoD, 2003a). "The <u>Program Manager</u> (PM) is the designated individual… accountable for credible cost, schedule, and performance" (DoD, 2003a). The "Defense Acquisition Management Framework" from DoDI 5000.2 is shown below.

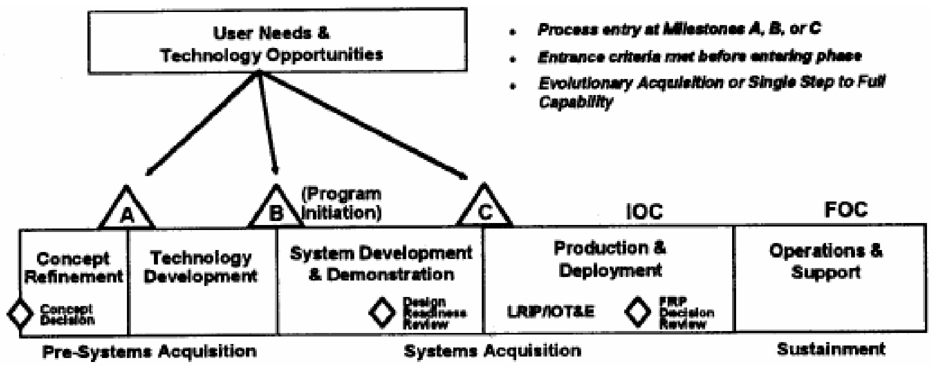


Figure 1. Defense Acquisition Management Framework (From DoDI 5000.2)

Within this framework, the program manager and the MDA (milestone decision authority) are given flexibility to "structure a tailored, responsive, and innovative program" (DoD, 2003b). The User Needs and Technology Opportunities represent the outputs of the Chairman of the Joint Chiefs of Staff "Joint Capabilities Integration and Development System [JCIDS]." The JCIDS process assists the JROC (Joint Requirements Oversight Council) "in identifying, assessing and prioritizing joint military capability needs" (Chairman of the Joint Chiefs of Staff, 2005). Within this process, a brand new idea would be initiated by a Concept Decision entry into the Concept Refinement phase. The purpose of this phase is "to refine the initial concept" and develop a Technology Development Strategy for use in the next phase. With a successful Milestone A decision, the Technology Development phase can begin. The purpose of this phase is "to reduce technology risk and to determine the appropriate set of technologies to be integrated into a full system" (DoD, 2003b). Technology Development ends when "an affordable increment of militarily-useful capability has been identified" and the associated technology has been demonstrated in "a relevant environment." A successful Milestone B decision follows the Technology Development phase and represents the first time the activity becomes a formal acquisition program. The next phase is System Development and Demonstration (SDD) and consists of two major efforts: System Integration and System Demonstration. A successful Milestone B decision may allow entry at either one of these. The general purpose of SDD is to develop the increment of capability, reduce risks, and conduct sufficient design activity to "demonstrate system integration, interoperability, safety, and utility" (DoD, 2003b). Following System Development and Demonstration is the Production and Deployment

phase. This phase follows a successful Milestone C decision and can only be entered if all of the entrance criteria (including but not limited to “acceptable performance in development, test and evaluation and operational assessment). The primary focus of this phase is to provide an operational capability that achieves mission needs and it also includes an operational test and evaluation. Finally, this phase includes the low-rate initial production (LRIP), if there is to be one, and the full-rate production decision. The final phase noted in the DoDI 5000.2 framework is the Operations and Support phase. There is no formal Milestone to initiate this phase and this phase starts as a natural progression of sustainment after fielding. The final phase culminates in disposal when a program has reached the end of its useful life. The MDA’s approval to proceed to each next phase is granted after the specific entrance criteria for the next phase are met. Specific entrance criteria for each phase shown in DoDI 5000.2 ensure the ensuing phase is executable, the program is viable, and there is a validated need to continue.

The purpose of the framework summarized above is “to acquire quality products that satisfy user needs with measurable improvements to mission capability and operational support, in a timely manner, and at a fair and reasonable price.” It is intended to be flexible and responsive and to provide affordable and timely systems to the users (DoD, 2003a). Flexibility exists to allow the MDA to determine the best point to enter the process and also to allow an evolutionary approach or a spiral development. These alternative approaches to acquisition allow a program to proceed into later phases of development while new spirals re-enter at an earlier phase in the process. Although this DoDD 5000.2 framework is intended to flexibly provide “quality products” within a “fair and reasonable price,” in 2004, then-Under Secretary of the Air Force (USecAF) Peter B. Teets, as the Space Milestone Decision Authority, granted a blanket waiver from utilizing the DoDI 5000.2 for all current and future programs to be executed by or under the authority of the AFPEO/SP (Air Force Program Executive Officer for Space). This waiver is documented in the USecAF memorandum “Update to the National Security Space Acquisition Policy 03-01,” dated 27 December 2004. Instead, national security space programs should follow the alternative acquisition approach described in the National Security Space Acquisition Policy 03-01.

D. SPACE SYSTEMS ENGINEERING AND ACQUISITIONS

On 27 December 2004, National Security Space Acquisition Policy 03-01 (NSSAP 03-01) was codified as a distinct approach to acquiring Department of Defense Space Systems apart from the standard DoDD 5000.1 acquisition approach. "The NSS [National Security Space] model emphasizes the decision needs for "high-tech" small quantity NSS programs, versus the DoD 5000 model that is typically focused on making the best large quantity production decision" (DoD, 2004). Additionally, NSSAP 03-01 focuses on a more efficient process, "[t]his policy describes the streamlined decision making framework for all DoD space system" major defense acquisition programs, to support the fact that, due to front-loaded funding profiles, the key decisions for space programs must typically be made much earlier in the program. Figure 2 shows a comparison of the DoDI 5000.2 process to that of NSSAP 03-01.

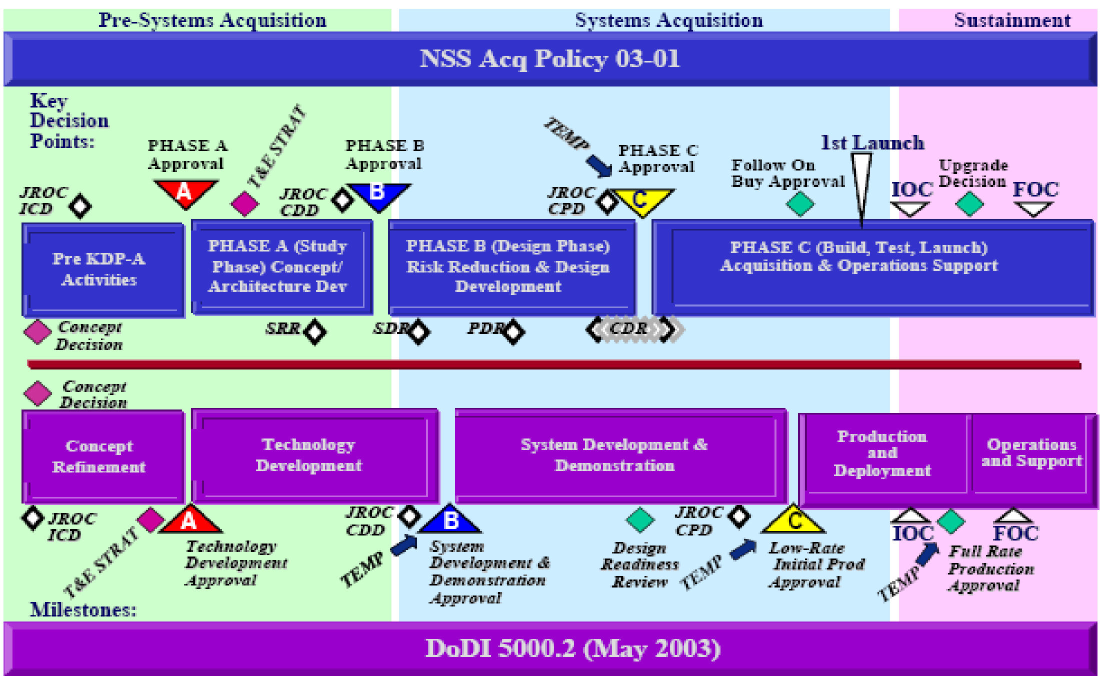


Figure 2. Acquisition Process Comparison (From NSSAP 03-01)

Although the basic phasing of the NSSAP 03-01 process is very similar to the framework of DoDI 5000.2, there are some key differences that make the acquisition process more adaptable to space acquisition programs. A greater emphasis is on achieving the Phase B and Phase C decisions (known as "Key Decision Points" or KDP in NSSAP 03-01) earlier. These earlier decisions force greater effort on early risk

reduction and more focus on architectural development instead of technology development. Additionally, there is a greater focus on getting requirements firmly established sooner. Not only are the JROC Capabilities Design Document (CDD) and Capabilities Production Document (CPD) approved earlier to support the earlier KDP, but there is a "System Requirements Review" (SRR) established as part of Phase A. Finally, another key distinction is the earlier entry into Phase C, the last phase. The earlier entry into Phase C allows much more time to conduct detailed testing prior to launch. For a space system, there is little chance to "re-do" a test if the launch is done pre-maturely. The additional time in the last phase for greater up-front testing allows for more risk reducing activities prior to launch of a satellite.

In establishing a separate acquisition process, the Under Secretary of the Air Force, as the Department of Defense Space Milestone Decision Authority, identifies four types of systems (DoD, 2004). These types of systems are sufficiently different from each other so as to require modified acquisition approaches. The different types of systems are 1) space based, 2) ground based, 3) satellite launch vehicle systems, and 4) user equipment. The NSSAP 03-01 document also places much more emphasis on systems engineering: "Robust [Systems Engineering] is essential to the success of any program. Program offices must focus attention on the application of SE principles and practices throughout the system life cycle, and they must elevate these SE principles *to a level commensurate with other programmatic considerations such as cost and schedule*" {emphasis not in original} (DoD, 2004).

In addition to recognizing these different types of systems, and therefore allowing greater flexibility in the acquisition system approach, NSSAP 03-01 also provides revised acquisition process acquisition frameworks for these differing types of systems – a small quantity program, a large quantity production program, and a revised process for evolutionary acquisitions. These acquisition frameworks are shown and described below in Figures 3, 4, and 5.

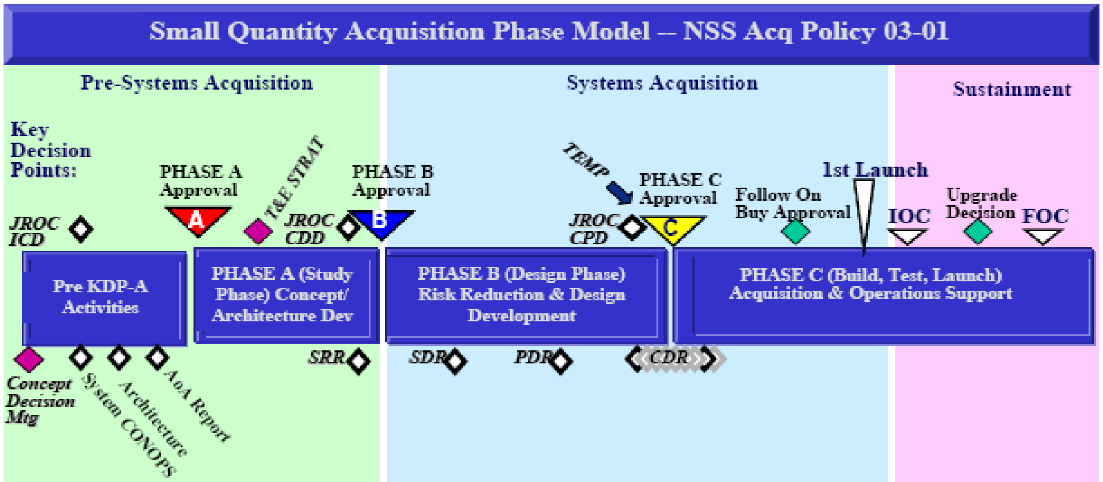


Figure 3. Small Quantity Model (From NSSAP 03-01)

The first of these alternative acquisition frameworks is the "Small Quantity System Model" shown in Figure 3. This framework typically would be applied to systems that are of the first three types according to NSSAP 03-01. Because these acquisitions are typically of low-quantity and high-cost, the initial activities are allowed greater time to mature. The initial design work in Phase B is of longer duration and takes place later than in the standard NSSAP model. The Phase C decision point happens much later in the process.

The second of these alternative acquisition frameworks is for a large quantity acquisition and is called the "Large Quantity Production Focused System Model." As shown in Figure 4, this acquisition framework from NSSAP 03-01 more closely resembles the typical DoDI 5000.2 framework and would apply to systems that would includes large quantities of production units, such as ground user equipment. Although this framework closely resembles the overall DoDI 5000.2 framework, this large quantity acquisition process from NSSAP 03-01 provides additional focus (compared to the DoDI 5000.2 framework) on requirements and testing.

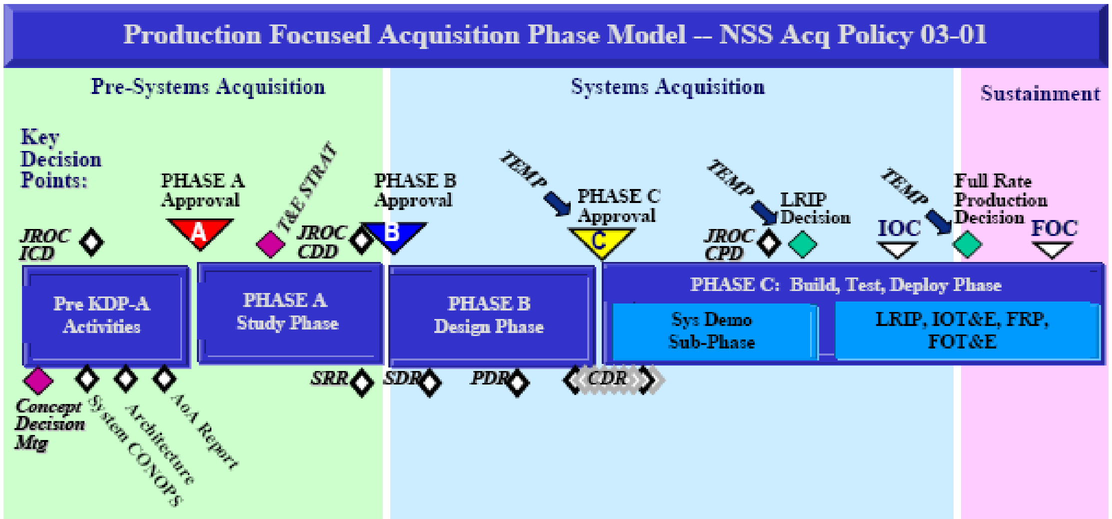


Figure 4. Large Quantity Model (From NSSAP 03-01)

Finally, the third variation of the NSSAP 03-01 acquisition model specifically applies to evolutionary acquisitions, shown in Figure 5. This alterative approach includes the necessary tie-in to an upgrade process (i.e., upgrade decision shown in the middle of Phase C). Additionally, this evolutionary process can be utilized with any initial framework as described in the previous section. Similar to the DoDI 5000.2 framework, the follow-on increments of capability would likely enter the process at Phase B (assuming a successful KDP).

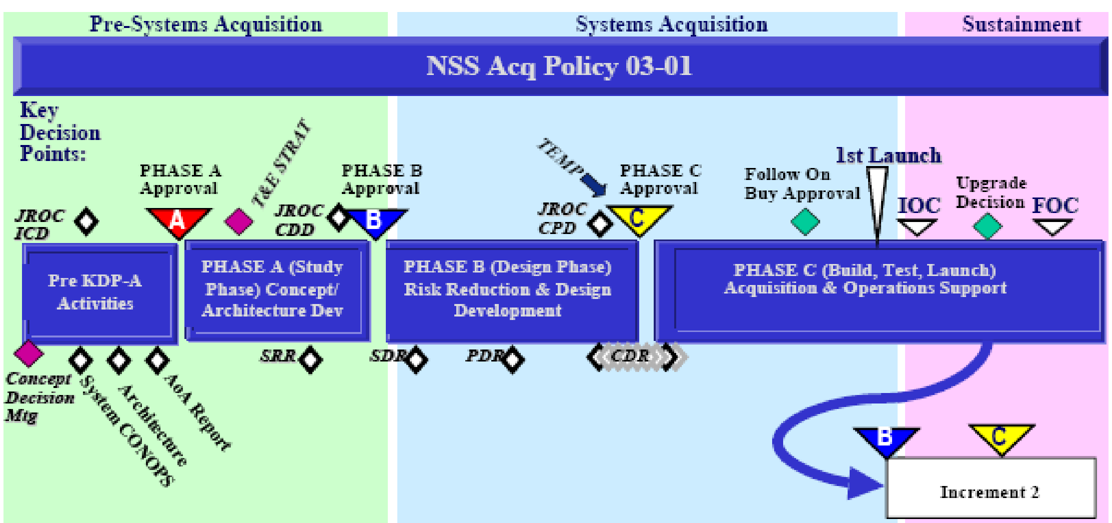


Figure 5. Evolutionary Model (From NSSAP 03-01)

Figure 6 shows one of the most critical pieces of information in the NSSAP 03-01 – the "DOD SPACE MDA GUIDING PRINCIPLES." As part of this "streamlined,

tailorable" acquisition process, systems engineering is much more a prominent part of the acquisition process than in the DoD 5000 processes and is a key part of the first guiding principle, namely, Mission Success. Overall, the Guiding Principles in Figure 6 from NSSAP 03-01 provide a solid grounding for systems engineers and acquisition managers of national security space programs and can be used by systems engineers to help define their role.

4. DOD SPACE MDA GUIDING PRINCIPLES

Over the first fifty years of the history of space acquisitions, several enduring principles have emerged. The following principles should be considered by all NSS members to set the tone and guide decision making in the acquisition of NSS systems:

a.) Mission Success: The overarching principle behind all National Security Space programs is mission success. When acquiring space systems, mission success must be the first consideration when assessing the risks and trades among cost, schedule, and performance. Risk management, test planning, system engineering and funding profiles must be driven by this objective.

b.) Accountability: The acquisition execution chain is ultimately accountable for a program's success or failure. The SPD/PM, as the leader of the Government-Contractor team for a program, must be accountable and have the authority to accomplish the program's objectives and meet the user's needs. The PEO or CAE and the DoD Space MDA have the responsibility to provide the SPD/PM with the resources and guidance necessary to accomplish these goals.

c.) Streamlined / Agile: The NSS acquisition team should work to reduce the acquisition decision cycle time and have short, clear lines of authority with decision making and program execution at the lowest levels possible. Staff elements, at all levels, exist to advise the acquisition decision making principals (i.e., DoD Space MDA, PEO, CAE, SPD/PM). No more than two layers can be between the SPD/PM and the MDA. (Ref: NSDD 219).

d.) Inclusive: Advice and information should be actively sought from all parties with an interest in NSS programs. A collegial/team relationship among all government, academia, and industry partners is the goal. DoD Space acquisition plans and documents should be coordinated with the appropriate lead user/operating command.

e.) Flexible: The "model" acquisition processes outlined in this document should be tailored to properly fit the circumstances of each NSS program. Only those activities, reports, plans, coordinations, or reviews required by statute or directed by the NSS acquisition execution chain are required.

f.) Stable: Within a given acquisition increment stable budgets, stable requirements, stable direction, and low personnel turnover are necessary for successful program acquisition. Decisions made by the acquisition execution chain must be durable.

g.) Disciplined: All parties to this space acquisition policy must exercise the discipline necessary to achieve its goals without allowing its procedures to become unnecessarily burdensome and/or time consuming.

h.) Credible: The NSS team must deliver what it promises on schedule and within budget. The NSS process is meant to incentivize and foster quality decision making for programs that exhibit the necessary maturity to proceed into the next acquisition phase.

i.) Cost Realism: The goal is to develop and grow a world class national security space cost estimating capability. Cost estimates must be independent and accomplished in a timely, realistic, and complete manner. Cost will be controlled by estimating accurately and focusing on quality to reduce rework and achieve mission success. All members of the NSS acquisition execution chain must insist on, and protect, a realistic management reserve.

Figure 6. Guiding Principles (From NSSAP 03-01)

Because space systems are inherently different from terrestrial based systems, NSSAP 03-01 has attempted to provide a more flexible framework with additional emphasis on risk reduction, systems engineering and requirements definition. The greater time in Phase C allows more complete testing prior to launch of the space vehicles. This emphasis is important for space systems because of the peculiarities of satellite systems engineering that will be discussed later.

E. SUMMARY

No single organization or document monopolizes systems engineering expertise. Simply by virtue of organizational culture, different organizations will treat systems engineering differently. As discussed thus far, the Space and Missile Systems Center takes a technical approach to defining the roles and responsibilities of a systems engineer and a systems engineering process. Although SMC also acknowledges the importance of good systems engineering to overall program performance, SMC provides little formal direction for the systems engineer to influence the cost or schedule of the program.

Within the Department of Defense, the core acquisition documents for DoD programs, DoDD 5000.1 and DoDI 5000.2 similarly lack any specific systems engineering direction or processes even though there is a direct acknowledgement of the importance of a "total systems approach" that includes technical performance. In part, because of the importance of good systems engineering principles to space systems, the Milestone Decision Authority for space programs instituted a separate acquisition framework for National Security Space programs in 2003. This policy, NSSAP 03-01, places significant emphasis on flexibility and systems engineering in order to attempt to more effectively and efficiently acquire space systems.

The Space and Missile Systems Center has formally documented some of the peculiarities of space systems and emphasized the need for good systems engineering to account for the peculiarities. This emphasis, combined with the flexible NSSAP 03-01 framework, has the potential to provide a thorough and powerful systems engineering process for space systems and space system acquisition. The crux of this research effort will attempt to discover and document trends in order to formulate recommendations on how the United States Air Force can improve its ability to effectively and efficiently acquire National Security Space systems.

III. LITERATURE REVIEW

A. INTRODUCTION

The acquisition problems associated with developing space systems are not new. Neither are the general acquisition problems associated with developing any system for the Department of Defense. According to Lance Lord (retired General, USAF, and former Commander, Air Force Space Command),

> The challenges we face have been around for longer than many of us realize. We are not the only ones who have wrestled with the best way to acquire military systems. In face, we have faced issues with acquiring high quality produces on time and on budget since the days of George Washington. In the last 200 years, more than 900 GAO reports, a dozen major commissions, and 4,000 studies have set their sights on the topic of military systems acquisition. Without question, we are dealing with an exacting and arduous issue. (Lord, 2005)

Although the pull for resources is a difficult problem in and of itself, as technology expands, dealing with the systems engineering required to develop and manage new systems has become a key factor in the acquisition process. In history, armies could simply “live-off-the-land,” but today, as weaponry have become more complex and armies have grown larger and could reach farther from home, the ability to logistically support an army became more difficult. With the advent of the Roman Legions, higher quality roadways were now needed to support troop movements. As technology has continued to expand and become more complex – faster with each passing century, decade, and year – dedicated resources and processes have become more and more critical to success. Never has this been more apparent than when the United States attempted to successfully launch and recover the classified Corona photo reconnaissance satellites. Managed by the Central Intelligence Agency (CIA), the CORONA effort was ultimately a highly successful space reconnaissance program but, in the beginning, the first 13 launches were extremely expensive failures for a variety of reasons (Wild Black Yonder, 1998.)

A problem in systems acquisition is that this process is just plain hard. Balancing the three critical parameters of cost, schedule, and performance/capability in the midst of

struggling with policy and strategy decisions and competing programs is a difficult endeavor. The Defense Department wants the best possible performance/capability as soon as possible. The Congress wants the cost to be low in order to support many Defense and non-Defense programs. In reality, although lots of ideas on "faster, better, cheaper" are tossed around, a program manager cannot have faster, better, and cheaper all at the same time because the three critical parameters are directly dependent on each other. Something has to be fixed in order to achieve the overall program objective. To date, the Congress and the Department of Defense have worked out a precarious balance by fixing yearly cost within the budget process. One of the unfortunate drawbacks of this balancing act is that it allows the schedule to be continually delayed which leads to increasing total costs which can further delay the schedule.

The remainder of this chapter contains a detailed investigation of the history of defense and space systems acquisition and engineering policy. How have the evolving acquisition policies impacted the skill set of USAF systems engineering personnel and their ability to support the systems acquisition process? Some of the peculiarities of space systems that make space systems engineering more difficult than traditional systems engineering will be elaborated and followed by a brief look at the Packard Commission of 1986, the acquisition reform initiatives of the mid-to-late 1990's, the 2001 Space Commission Report, the 2003 Young Panel, and the 2005 Defense Acquisition Performance Assessment Project. Each of these initiatives has impacted, both positively and negatively, the ability of United States Air Force personnel to do their jobs in systems engineering in support of space systems acquisition. This chapter ends with a brief examination of a few programs that have been deemed by history to be either successful or not-so-successful.

B. PECULIARITIES OF SPACE SYSTEMS

One of the primary distinctions between a satellite and a traditional Earth-bound system is the satellite must operate in a much harsher environment and must be error-free before launch. The launch aspect is critically important because, in large part, it drives the normally exorbitant cost of fielding space systems. However, space programs are not just driven by a different funding-profile; rather there are severe technical challenges present for a space program that do not exist for a general acquisition. Primarily, these

challenges result from the space environment, unattended operation in orbit, and the inherent joint-nature of space programs (SMC). According to the United States Air Force military standard (MIL-STD-1809) "Space Environment for USAF Space Vehicles," "vehicles operating in the space environment experience various effects caused by the vacuum, radiation, and particulate environments, as well as inertial effects" (Department of the Air Force, 1991).

A satellite must be designed to not only survive, but also to operate reliably in the harsh orbital environment. The satellite deals with near-total vacuum, extreme and rapidly variable thermal conditions/cycles, as well as radiation and magnetic fields not present on Earth. The systems engineering process must account for the derived requirements relating to the harsh orbital environment as well as the test and integration requirements of such stringent aspects of system design (SMC, 2005).

A space system must also be capable of unattended operation. This requires the program office to "get it right before launch." That is, however, not the only requirement. Because the space system will be unattended, sufficient hardware and software redundancy must exist to provide sufficient margin to meet reliability requirements. Moreover, the space system software should be re-loadable, on-orbit, to the maximum extent possible to allow for system anomaly resolution, which, for hardware, is simply not feasible without redundancy. Overall, a robust space system capability requires many unique considerations: the use of high reliability parts, extensive modeling and simulation, reduction/elimination of single-point-failure items, and higher design margins, just to name a few. "Experience shows that the cost of these steps together with the cost of space launch [i.e., getting the system to space] is perhaps ten times or more the cost of comparable hardware deployed in terrestrial applications" (SMC, 2005).

The extraordinary cost premium of space equipment means that each system must be exploited to the maximum extent possible "by all land, sea, and air forces" (SMC, 2005). This mentality places a great deal of pressure on all space systems to be joint-service in nature. This joint acquisition mind-set leads to difficulties in communications and processes as well as system interoperability (design, verification and test). Also,

because these space systems will likely be exploited by a large number of end-users, the cost of the user equipment on the ground can "rival or even exceed" the cost of satellites, so the task of balancing system-level risk, performance/capability, cost and schedule is fundamentally more difficult, yet more critical than terrestrial based systems (SMC, 2005).

C. SPACE SYSTEMS ACQUISITION POLICY REVIEW

1. History of Space Systems Acquisition

Prior to the creation of the first NSSAP 03-01, there was no official difference between space systems acquisition and traditional Department of Defense systems acquisition. Before the Air Force Space Command's initiative to create a space cadre, there was no distinction in training for space system engineering or acquisition personnel as opposed to systems engineering or acquisition personnel within the rest of the Air Force. Today, even with the advent of the AFSPC's space cadre initiative, there is no recognizable distinction in career field for a space systems engineer. The following reports, commissions, and efforts have been reviewed because they have all left a lasting impact on space systems engineering and therefore space systems acquisition. Not all of these impacts were intentional, and not all were necessarily for the betterment of space systems engineering. The findings resulting from the review of theses reports, commissions, and efforts will be discussed in Chapter IV.

2. Packard Commission

> The President [former-President Ronald Reagan] established the Blue Ribbon Commission on Defense Management in part because public confidence in the effectiveness of the defense acquisition system has been shaken by a spate of 'horror stories'—overpriced spare parts, test deficiencies, and cost and schedule overruns… A major task of this Commission has been to evaluate the defense acquisition system, to determine how it might be improved, and to recommend changes that can lead to the acquisition of military equipment with equal or greater performance but at lower cost and with less delay. (Blue Ribbon Commission on Defense Management, 1986)

This Commission, chaired by David Packard, focused on defense acquisition practices and on how to reduce the cycle-time of developing major weapon systems.

The Packard Commission concluded that the defense acquisition process was fraught with "basic problems that must be corrected" (Blue Ribbon Commission on

Defense Management, 1986). These problems "are deeply entrenched and have developed over several decades from an increasingly bureaucratic and overregulated process." According to the Commission, the end result caused by these basic problems is weapon systems will cost too much, take too long, and not perform as required. The following excerpts from the Packard Commission's Formula for Action show how similar defense acquisition in 1986 is to the space systems acquisition environment of today.

> In general, we discovered, these problems were seldom the result of fraud or dishonesty. Rather they were symptomatic of other underlying problems that affect the entire acquisition system.
>
> Once military requirements are defined, the next step is to assemble a small team whose job is to define a weapon system to meet these requirements, and "market" the system within the government, in order to get funding authorized for its development. Such marketing takes place in a highly competitive environment, which is desirable because we want only the best ideas to survive and be funded. It is quite clear, however, that this competitive environment for program approval does not encourage realistic estimates of cost and schedule. So, all too often, when a program finally receives budget approval, it embodies not only overstated requirements but also underestimated costs.
>
> DoD then invites industry to bid on the program… This [the environment of cost competition] effectively forecloses one principal factor—trade-offs between performance and cost—on which the competition should be based. The resulting competition, based instead principally on cost, all too often goes to the contractor whose bid is the most optimistic.
>
> In underbidding, contractors assume there will be an opportunity later in a program to negotiate performance trade-offs that make a low bid achievable, or to recover understated costs through engineering change orders.
>
> In the face of these daunting problems, DoD selects a successful bidder and launches the program. The DoD program manager sets out to accomplish the improbable task of managing his overspecified and underfunded program to a successful conclusion.
>
> But what was merely improbable soon becomes impossible. The program manager finds that, far from being the manager of the program, he is merely one of the participants who can influence it. An army of advocates for special interests descends on the program to ensure that it complies with various standards for… reliability, maintainability, operability, small

> and minority business utilization, and competition, to name a few. Each of these advocates can demand that the program manager take or refrain from taking some action, but none of them has any responsibility for the ultimate cost, schedule, or performance of the program.
>
> None of the purposes they advocate is undesirable in itself. In the aggregate, however, they leave the program manager no room to balance their many demands, some of which are in conflict with each other, and most of which are in conflict with the program's cost and schedule objectives. Even more importantly, they produce a diffusion of management responsibility, in which everyone is responsible, and no one is responsible.
>
> Meanwhile, throughout this process, various committees of Congress are involved. During the marketing phase, it is not enough for the program manager to sell the program to his Service leaders and the various staffs in the Office of the Secretary of Defense. He also must sell the program to at least four committees and to numerous subcommittees of Congress, and then resell it for each fiscal year it is considered. In so doing, the program manager is either assisted or opposed by a variety of contractors, each advocating its own views of the program on Capitol Hill. While congressmen have an abstract interest in greater program effectiveness, they also have an intense pragmatic interest in their own constituencies. These two interests are frequently in conflict, as they exert pressure on specific programs through legislative oversight.
>
> All of these pressures, both internal and external to DoD, cause the program manager to spend most of his time briefing his program. In effect, he is reduced to being a supplicant for, rather than a manager of, his program. The resulting huckster psychology does not condition the program manager to search for possible inconsistencies between performance and schedule, on the one hand, and authorized funding, on the other. Predictably, there is a high incidence of cost overruns on major weapon systems programs.
>
> This description of the acquisition system is stark, but it by no means exaggerates the environment of many, if not most, defense programs. Given this pernicious set of underlying problems, it is a tribute to the dedication of many professionals in the system, both in and out of DoD, that more programs do not end up in serious trouble. (Blue Ribbon Commission on Defense Management, 1986)

To combat the basic underlying problems of the acquisition process, the Packard Commission studied several models of success and made several recommendations based on its findings. The Commission looked at the IBM 360 computer, the Boeing 767, and the Hughes communications satellite. These programs were selected because the

Commission determined they were comparable in “complexity and size” to a typical major weapon system for the DoD. Each of these programs took roughly half as long to develop as a major weapon system. The Commission also investigated several DoD efforts that were managed under what it called “streamlined procedures.” These efforts included the Polaris missile, Minuteman missile, Air Launched Cruise Missile, and several “highly classified projects.” The Commission found these DoD programs were able to meet acquisition cycles roughly equivalent to the non-DoD efforts noted above. After looking at the similarities of each of these efforts, the Packard Commission listed six characteristics they all had in common: 1) clear command channels, 2) stability, 3) limited reporting requirements, 4) small, high-quality staffs, 5) communication with users, and 6) prototyping and testing. Based on these findings, the Commission made seven recommendations to improve DoD weapon system acquisition:

- Streamline Acquisition Organization and Procedures
- Use Technology to Reduce Cost
- Balance Cost and Performance
- Stabilize Programs
- Expand the Use of Commercial Products
- Increase the Use of Competition
- Enhance the Quality of Acquisition Personnel

The effectiveness, or lack thereof, of the Packard Commission’s recommendations will be discussed in detail in Chapter IV.

3. Acquisition Reform

The Acquisition Reform initiatives of the 1990’s are different from the Packard Commission, the Space Commission, and the Young Panel to be discussed later. While each of the Commissions/Panels was a concerted study of the health and status of the then-present DoD acquisition system, the acquisition reform initiatives were a series of efforts spanning most of the decade to enact sweeping change and commercial practices in the DoD acquisition system. The Defense Science Board (DSB) conducted a number of studies from 1993 through 1999 to make several recommendations. Though not all

were enacted, the reform environment of the 1990's created profound cultural changes throughout the entire DoD acquisition system. The following description provides a general overview of the DSB reports on this topic through the years of 1993 - 1999.

In 1993, the first DSB report on acquisition reform was published and provided to the Undersecretary of Defense (Acquisition). This report was not based solely on reducing the cost of the acquisition process, rather, it set out to investigate and provide recommendations regarding how to "reconnect and integrate defense acquisition with the commercial workplace from which it has been drifting apart at a steady rate" (Defense Science Board, 1993). The DSB focused on the following issues:

- Major barriers to the use of commercial practices, facilities, and equipment
- Primary sources of excessive costs in the current acquisition process
- Lack of flexibility, reality, and affordability in the current program definition process (or requirements process)
- Need to ensure public trust while implementing improvements

In the DSB's research, the use of commercial best practices, broad use of competition instead of rigid cost controls, and flexibility in the requirements process were all emphasized. The following specific recommendations were intended to bring about these changes:

- Broaden the procurement of commercial products
- Increase the use of simplified procurement procedures
- Reduce reliance on cost or pricing data

Additionally, the DSB recommended an increased use of commercial practices in what it called 'key industrial sectors.' These key industrial sectors included:

- Pilot initiatives (electronics and jet engines) to utilize commercial practices for new procurements
- Focus on technology insertion and requirements process

- Prepare the first of an annual series of commercialization plans to implement commercial practices
- Establish an outside standing Review Group
- Establish a comprehensive education, training, communications, and outreach program for government, industry, and the public

A little more than one year later, the DSB conducted and released the second phase of defense acquisition reform initiatives, known as Phase II. The primary focus of this Phase II study was to further define and determine the feasibility of the pilot industry initiatives that were recommended in the Phase I study (Defense Science Board, 1994). In Phase II, the DSB concluded:

- Mature jet engines, microelectronics, software, and space systems can and should be procured and supported in a fully commercial environment.
- The combatant commanders should be given increased technical cadres to further their capability to participate in the requirements process.
- It is feasible to eliminate many of the barriers to adoption of commercial practices without sacrificing the public trust in spending public funds.

Although numerous specific recommendations were provided, the primary conclusion of the Phase II study was the feasibility to press forward with commercialization initiatives. The DSB Task Force recommended the establishment of comprehensive programs to begin commercializing key industries where possible (jet engines, microelectronics and mature space efforts) as well as follow-up studies to investigate the ability to fully commercialize large-scale research and development efforts (including space). Furthermore, a renewed emphasis on competition, a reduction of standards and regulations, as well as operational influence on the requirements process were all key tenants of the Phase II study.

The “Report of the Defense Science Board Task Force on Defense Acquisition Reform (Phase III)” was released in mid-1996. In Phase III, this Task Force focused on “evaluating the possibility of extending best-of-class practices to the research and development phase of a system’s acquisition” (Defense Science Board, 1996). The key

findings from Phase III continued to support the initial findings of the Phase I study. “The current acquisition process is outmoded, too expensive, too lengthy, and should be replaced; instead, the research and development phase of military systems should adopt best commercial practices.” Additionally, the conclusions from Phase III again emphasized the need for increased operational involvement with the requirements process and the use of a competitive environment instead of a cost-type environment for development programs. The Task Force recommended the following specific measures to begin implementing a commercialized research and development environment:

- A broader understanding and implementation of effective and continuous competition
- Carefully structured, relatively short, fixed price/flexible performance contracts
- A rigorous risk-reduction phase before full system development
- Including contractor past performance on commercial and military programs and on process maturity as significant factors in source selection
- The participation of government representatives on the integrated product teams
- Curtailing efforts early when performance fails or cost objectives are not achieved
- Buying in quantity only after system demonstration and user buy-off

This type of a “phased, competitive model” to research and development “will permit DoD to develop and acquire weapons systems faster, better, and at lower cost” (Defense Science Board, 1996).

Published in 1999, a fourth study report (Phase IV) recommended a set of metrics by which to measure the initiatives put forth in the previous Task Force reports. The effectiveness, or lack thereof, of these reform initiatives will be discussed in Chapter IV.

4. Space Commission

Directed by the National Defense Authorization Act for Fiscal Year 2000 (Public Law 106-65) to assess the organization and management of space activities that support U.S. national security interests, the Space Commission delivered its report on 11 January 2001. The Commission's charter, not just limited to or even focused on a review of national security space acquisition, was to undertake a holistic review of the national security space strategy, vulnerability, and approach for the future. Though space systems engineering/acquisition is just one small facet of this commission's charter, a review of this Commission is included as part of this research effort, because some of the conclusions and recommendations by this Commission were then an admonition of the space acquisition community in general.

The 2001 Space Commission "unanimously concluded that organizational and management changes are needed." This shake-up of the national security space community was deemed necessary because of the key findings by the Commission. All five of the Commission's key findings include criticism of the United States Government's handling of national security space and, in some manner; each of them pertains to space systems acquisition.

"First, the present extent of U.S. dependence on space, the rapid pace at which this dependence is increasing and the vulnerabilities it creates, all demand that U.S. national security space interests be recognized as a top national security priority… Only the President has the authority, first, to set forth the national space policy, and then to provide the guidance and direction to senior officials, which together are needed to ensure that the United States remains the world's leading space-faring nation." Though not a direct criticism of the lower level acquisition organizations, this finding bluntly provides warning that our nation is vulnerable to a "Space Pearl Harbor" and it will require action from the President of the United States to make space be a part of the U.S. national security as is required.

"Second, the U.S. Government—in particular, the Department of Defense and the Intelligence Community—is not yet arranged or focused to meet the national security space needs of the 21st century. Our growing dependence on space, our vulnerabilities in

space and burgeoning opportunities from space are simply not reflected in the present institutional arrangements…" This is one of the most poignant indictments of the space engineering/acquisition community and directly calls in to question the community's ability to meet the space needs for today and the future.

"Third, U.S. national security space programs are vital to peace and stability, and the two officials primarily responsible and accountable for those programs are the Secretary of Defense and the Director of Central Intelligence… They must work closely and effectively together, in partnership, both to set and maintain the course for national security space programs and to resolve the differences that arise between their respective bureaucracies." With this finding, the commission calls into question the ability of the highest levels of the national security space bureaucracy to provide the capabilities and information required "to pursue our deterrence and defense objectives in this complex, changing and still dangerous world."

"Fourth, we know from history that every medium—air, land and sea—has seen conflict. Reality indicates that space will be no different… Thus far… the U.S. has not yet taken the steps necessary to develop the needed capabilities and to maintain and ensure continuing superiority." This finding is also not a direct criticism of the engineering/acquisition process, yet it serves as a warning that the community needs to be ready to develop and delivery the needed capabilities when called upon to do so.

"Finally, investment in science and technology resources – not just facilities, but people – is essential if the U.S. is to remain the world's leading space-faring nation. The U.S. Government needs to play an active, deliberate role in expanding and deepening the pool of military and civilian talent in science, engineering and systems operations that the nation will need." According to the Commission's report, this is one of the fundamental problems in dealing with the high tech world of space: growing the right people to do the right jobs when needed.

Although all five of these findings do contain criticism of and/or warnings to the space engineering/acquisition community, the second and fifth findings are particularly accurate. Later, the Commission states "The U.S. will not remain the world's leading space-faring nation by relying on yesterday's technology to meet today's requirements at

tomorrow's prices." To address these findings and this problem inherent in the development and fielding of national security space systems, the Space Commission put forth several areas for improvement. "The U.S. Government must work actively to make sure that the nation has the means necessary to advance its interests in space. This requires action in the following areas:

- Transform U.S. Military Capabilities
- Strengthen Intelligence Capabilities
- Shape International Legal and Regulatory Environment
- Advance U.S. Technological Leadership
- Create and Sustain a Cadre of Space Professionals"

One of the overarching recommendations of the Space Commission to address the shortfalls noted above was to lay the foundation for the emergence of a Space Corps within the Department of the Air Force or a Department of Space distinct from the other military departments. The Commission stated:

> The Department of Defense requires space systems that can be employed in independent operations or in support of air, land and sea forces to deter and defend against hostile actions directed at the interests of the United States. In the mid term, a Space Corps within the Air Force may be appropriate to meet this requirement; in the longer term, it may be met by a military department for space. In the nearer term, a realigned, rechartered Air Force is best suited to organize, train and equip space forces. (Space Commission, 2001).

Towards this end the Commission provided the following specific recommendations.

- Realign the Space and Missile Systems Center under a 4-star General in command of Air Force Space Command. At the time of this recommendation, the Space and Missile Systems Center was assigned to the Air Force Materiel Command and was responsible for the research, development and fielding of all space systems developed by the United States Air Force.
- Amend Title 10 U.S.C. to add the phrase "and space" to the responsibility of the United States Air Force. This would assign, by statute,

responsibility to organize, train and equip space forces to the United States Air Force.

The Commission also made several specific recommendations to bring about a closer alignment of the National Reconnaissance Office (NRO) and the Air Force. These recommendations were intended to bring about a more streamlined acquisition process for national security space programs and foster the sharing of "best practices" between the Air Force and the NRO.

- Align Air Force and NRO space programs by designating the Under-Secretary of the Air Force as the Director, NRO.
- Designate the Air Force as the Executive Agent for Space. This action would create a single acquisition agent for all Department of Defense space acquisitions.

The Commission concluded that "the Department of Defense is not yet on a course to develop the space cadre the nation needs. The Department must create a stronger military space culture, through focused career development, education and training, within which the space leaders for the future can be developed." The combined recommendations to realign the SMC to AFSPC and designate the USecAF as Director of the NRO not only provide a foundation for the Space Commissions mid-term solution of a Space Corps, but these recommendations also provide the underpinning for the creation and sustainment of "a cadre of space professionals." By consolidating all space acquisition and operations activities under a 4-star Commander, Air Force Space Command, a single organization led by a single commander, can be put in charge of "managing all aspects of the space career field" and made responsible for creating "an environment in which to develop a cadre of space professionals… charged with developing doctrine, concepts of operations and new systems to achieve national space goals and objectives. The arrangement would increase the role of the uniformed military in research, development and acquisition of space systems to better meet operational requirements."

The effectiveness, or lack thereof, of the Space Commission's recommendations will be discussed in detail in Chapter IV.

5. Young Panel

> Significant cost growth and schedule delays in many critical space system programs have caused senior DoD and Intelligence Community leadership to question our nation's ability to acquire and sustain national security space systems. The recent series of problems comes at a time when our nation has been growing increasingly reliant on space systems to perform military and intelligence operations. (Defense Science Board, 2003)

In August 2002, then-Under Secretary of Defense (Acquisition, Technology & Logistics) [USecDef(ATL)] E.C. "Pete" Aldridge, then-Secretary of the Air Force James Roche, and then-Undersecretary of the Air Force/Director of the NRO (DNRO) Peter Teets chartered the Defense Science Board Task Force on Acquisition of National Security Space Programs. This Task Force was "asked to investigate systemic issues related to space systems acquisition, to include all aspects from requirements definition and budgetary planning through staffing and program execution; and to recommend improvements to the acquisition of space programs from initiation to deployment."

Within the Terms of Reference Memorandum, establishing the Task Force by then-USecDef(ATL) E.C. "Pete" Aldridge, the state of national security space systems acquisition is described very bleakly:

> The health of our Nation's ability to acquire and sustain national security space systems has become a serious question with the top leaders in the Department of Defense in the wake of significant cost growths and schedule delays for many critical space systems procurements. This concern about the acquisition of national security space systems comes at a time when our nation is growing increasingly reliant on space systems for both military and intelligence operations. We need to think strategically about the vulnerabilities arising from this dependency and whether we are becoming too dependent on space. In order to characterize the problem it is necessary to understand the underlying causes of the community's problem and identify any systemic issues.

At the conclusion of their efforts, the Task Force did indeed find significant systemic issues in the national security space acquisition process. The Task Force found five primary reasons for cost growth and schedule delays:

- Cost has replaced mission success as the primary driver in managing space development programs.

- Unrealistic estimates lead to unrealistic budgets and unexecutable programs.
- Undisciplined definition and uncontrolled growth in system requirements increase cost and schedule delays.
- Government capabilities to lead and manage the space acquisition process have seriously eroded.
- Industry has failed to implement proven practices on some programs.

The Young Panel put forth these reasons for cost and schedule problems in national security space acquisition against the backdrop of significant changes in the 1990's. According to the Young Panel, the following changes took place in the 1990's in the national security space environment:

- Declining acquisition budgets
- Acquisition reform with significant unintended consequences
- Increased acceptance of risk
- Unrealized growth of a commercial space market
- Increased dependence on space by an expanding user base
- Consolidation of the space industrial base

These changes took place because the entire Department of Defense was attempting to make the transition from "the structured cold war environment to the more global and unpredictable threat environment we see today." In order to correct some of the problems created by this changing environment, the Young Panel made several specific recommendations for immediate implementation. These specific recommendations are:

- *Mission Success* should be established by the USecAF/DNRO as the "guiding principle in all space systems acquisition." {emphasis in original}

- The Secretary of Defense should provide the USecAF the same authority for implementing DoD space programs as the DNRO has for implementing the National Reconnaissance Program budget.
- The USecAF/DNRO should help ensure realistic budgets and cost estimates.
- The USecAF/DNRO should only compete space systems acquisitions "when *clearly* in the best interest of the government and provisions "must be made to assure continuity between the legacy system and the new system." {emphasis in original}
- The Secretary of Defense and the Director of Central Intelligence should designate senior leaders with the authority to lead and assess requirements processes and couple the requirements with funding constraints.
- The program managers should be allowed to control their own programs within a USecAF/DNRO approved baseline and be allowed to trade requirements throughout the program.
- "The Commander, Air Force Space Command, should complete the ongoing effort to establish a dedicated career field for space operations and acquisition personnel."
- Key program management positions should be linked to a minimum tour-length of four years.
- The USecAF/DNRO should more clearly define the "responsibility, authority, and accountability for program managers, recognizing the criticality of program managers to the success of their programs."
- The USecAF/DNRO should "develop a robust systems engineering capability" by reestablishing an "organic government systems engineering capability" and more fully utilizing the "combined capabilities of government, Federally Funded Research and Development Center

(FFRDC), and systems engineering and technical assistance (SETA) system engineering resources.”

- Program managers should be required to identify and report problems early by establishing early warning metrics and “severe and prominent penalties should follow any attempt to suppress problem reporting.”
- National security space contractors should be required to account for the quality of their program and for mission success, identify and use best program management and engineering practices and be accountable for early identification of problems.
- Contract and fee structures should be aligned “to focus industry attention on proven management and engineering practices and mission success.”

In putting forth these specific recommendations, the Young Panel hoped to correct the problems it noted and allow the national security space acquisition system to focus on producing the required systems. The Young Panel also noted that further cost and schedule overruns would assure mission failures if the actions were not taken to correct the current problems. Finally, the Young Panel stated that even “if all of the corrections recommended in this report are made, national security space will remain a challenging endeavor, requiring the nation’s most competent acquisition personnel, both in government and industry.”

6. Teal Group

In late 2005, the Teal Group was asked to answer the following question: “Is there something inherent in military satellite technologies that makes them prone to technical setbacks and cost increases?” The Teal Group’s findings were published in Aerospace America in January 2006. Their leading conclusion states “Whether or not cost overruns are inherent in U.S. military satellites under development, we cannot say for sure. We can say that these overruns seem to be endemic” (Cáceres, 2006). As part of its research, the Teal Group studied 10 “major satellite systems” under development by the Department of Defense. The following programs and their descriptions from the Teal Group’s investigation are incorporated here..

Advanced Extremely High Frequency (AEHF). This program is intended to be the follow-on to the USAF MILSTAR military communications system.

Future Imagery Architecture (FIA). This program is intended to follow the National Reconnaissance Office's electro-optical and radar imaging surveillance and reconnaissance satellites.

Global Positioning System (GPS) IIR-M/IIF. The GPS IIR-M and GPS-IIF efforts comprise a "piece-meal" modernization program for GPS-IIR.

GPS-III. GPS-III is intended to be the "full-fledged" modernization for the entire GPS constellation.

Mobile User Objective System (MUOS). This is a U.S. Navy (USN) program and is intended to be the eventual replacement of the current USN constellation of communications satellites (Navy Fleet Satellite).

National Polar-orbiting Operational Environmental Satellite System (N-POESS). N-POESS is a combined effort between the USAF and the National Oceanic and Atmospheric Administration (NOAA). It is intended to be the follow-on to the current USAF Defense Meteorological Satellite Program (DMSP) and the NOAA Polar Operational Environmental Satellites (POES).

Space Based Infrared System-High (SBIRS-High). This system is intended to be the "geostationary orbiting segment of a two-tiered ballistic missile early-warning satellite constellation" and makes up one piece of the follow-on to the Defense Support Program (DSP).

Space Radar (SR). This is the third iteration of a program formerly called Starlite in 1996 and then Discoverer II in 1997. It is intended to provide a radar reconnaissance capability.

Space Tracking and Surveillance System (STSS). Along with SBIRS-High, STSS helps complete the follow-on to the DSP. STSS is intended to be a constellation of missile tracking satellites in low-earth-orbit. It is the successor of two previously cancelled programs – Brilliant Eyes from the 1980's and more recently SBIRS-Low.

Wideband Gapfiller Satellites (WGS). WGS is intended to augment the USAF Defense Satellite Communications System (DSCS) and the USN Global Broadcast Service (GBS).

A quick run-down of the Teal Group's primary conclusions from each one of these programs gives the best snap-shot of the current state of national security space acquisitions and is shown in Table 1.

Program	***Cost Overrun***	***Schedule Delay***	***Cause***	***Program Impacts***
AEHF	100%	4 years	Technology delays	Smaller constellation will be deployed
FIA	100%	>4 years	Technology delays	Numerous "restructures"
GPS IIR-M/IIF	20%	-	GPS-III delays	Fewer satellites built / deployed
GPS III	-	~3-6 years	Government indecision	Costly "modernization" program required
MUOS	-	~3 years	Too optimistic	Budget increased early on; continually being stretched out
N-POESS	~33%	> 4 years	Technology delays	Technology demonstration cancelled; reduction in deployed capability
SBIRS-High	>150%	> 5 years	Technology delays	4 "Nunn-McCurdy" violations; 2 in a single year
SR	At Risk	At Risk	Unclear requirements; technology	Cancelled and re-named twice since 1996; latest iteration was almost 200% over budget when cancelled
STSS	At Risk	-	Technology delays	Cancelled and re-named twice since 1980's; latest iteration was more than 100% over budget when cancelled
WGS	At Risk	~ 2 years	Design and integration delays	Launch delays; program restructures

Table 1. Teal Group Program Summary

The Teal Group's survey of national security space program troubles is certainly not the only current indicator that the space acquisition process is still in trouble. Although the Teal Group did not offer any specific recommendations on correcting the "endemic problems" they identified, the Defense Acquisition Performance Assessment (DAPA) Project from the same timeframe did. The DAPA Project's assessment of the current status of space acquisition and its recommendations will be discussed in the next section.

7. Defense Acquisition Performance Assessment Project

In June 2005, acting Deputy Defense Secretary Gordon England "authorized a sweeping and integrated assessment to consider 'every aspect' of acquisition." The authorization led to the Defense Acquisition Performance Assessment (DAPA) Project. At the time, during Mr. England's confirmation hearings, it became clear that the "Congress and Department of Defense senior leadership have lost confidence in the Acquisition System's ability to determine what needs to be procured or to predict with any degree of accuracy what things will cost, when they will be delivered, or how they

will perform" (Assessment Panel of the Defense Acquisition Performance Assessment Project [DAPA], 2005). According to the DAPA Executive Summary, the Fiscal Year 2006 House and Senate Defense Authorization Committee Reports issued concern over the DoD's acquisition system's ability to produce and procure required capabilities within reasonable cost. Additionally, the Committee reports "stated that addressing symptoms one program or one process at a time is unlikely to result in substantial improvement" (DAPA).

The DAPA Project produced the following major findings shown in Figure 7.

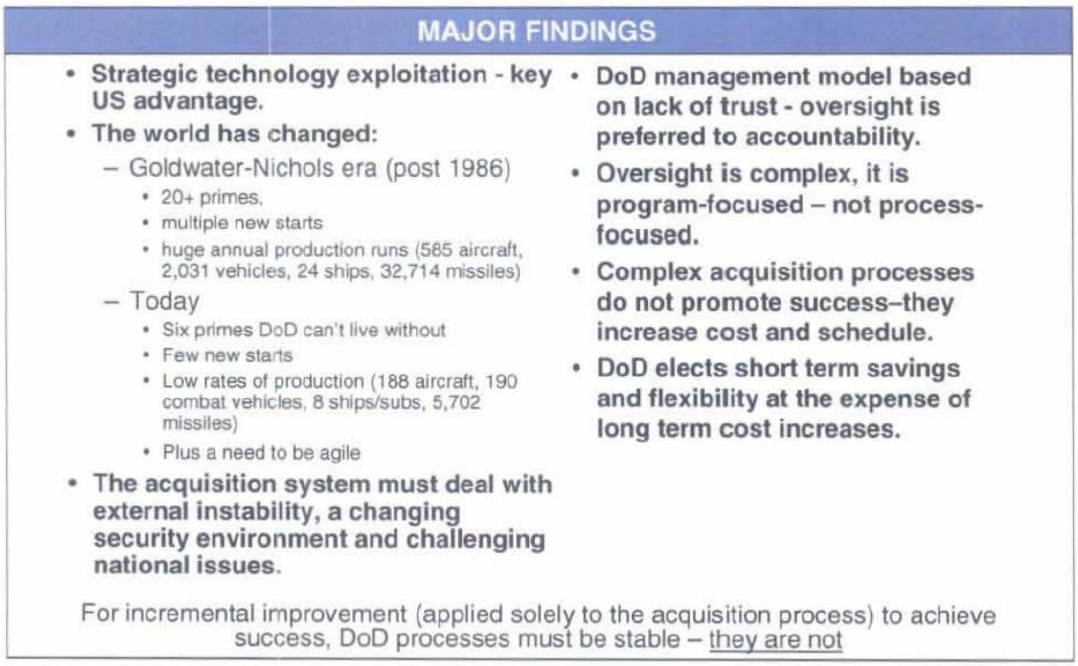


Figure 7. DAPA Project Major Findings (From DAPA)

The DAPA Project also concluded that the net effect of "incremental improvements to a narrowly defined acquisition process" over the last few decades of acquisition reform initiatives has been detrimental to the DoD acquisition system. Because the acquisition system relies on external processes and organizations (i.e., "oversight, budget and requirements" as well as the parent organizations of these processes), in order for the reform initiatives studied by the DAPA Project to have been effective the external processes and organizations would have to have been stable – which they were not (DAPA, 2005).

Although the purpose of the DAPA Project was not to deal specifically with space systems acquisition or engineering, many of the DAPA recommendations apply to the entire realm of DoD acquisition and the Air Force led space systems acquisition. The DAPA Project recommended an "integrated transformation of the major elements of the larger Acquisition System that can reduce cost, enhance acquisition performance and accelerate by years the delivery of key capabilities" by reducing "government-induced instability" (DAPA, 2005). Figure 8 summarizes these recommendations.

Figure 8. DAPA Project Recommendations (From DAPA)

These recommendations reflected the DAPA Project focus on stability – stability in funding, stability in requirements, and stability in process. Furthermore, the DAPA Project emphasized the "value [of] the acquisition workforce" and recommended it be rebuilt and leadership be encouraged.. These DAPA recommendations will also be addressed in Chapter IV.

D. REVIEW OF PAST AIR FORCE SYSTEMS ENGINEERING PROGRAMS

1. Successful Programs

a. Discoverer/CORONA

In August 1960, the film recovered from Discoverer XIV provided the first images of Earth ever taken from space (Wild Black Yonder). Discoverer was the

unclassified cover story for the closely held Central Intelligence Agency (CIA) program code-named CORONA. This first successful CORONA mission was a critical victory for the United States intelligence community. This mission provided photographs covering over one million square miles of Soviet territory – "greater than that produced by all of the U-2 overflights over the Soviet Union" (Richelson).

Because of its impacts on dispelling the "missile gap" and its many technological firsts, the Discoverer/CORONA program has been viewed as a very successful endeavor for the United States efforts in space. According to the "Historical Overview of the Space and Missile Systems Center" by SMC, the most important aspect of the Discoverer/CORONA program was it "filled a crucial need" for the Eisenhower administration. After the downing of Francis Gary Powers' U-2 reconnaissance aircraft, the administration ceased all airborne reconnaissance efforts over the Soviet Union and was effectively blind in regards to the real nature of the Soviet missile threat. Throughout the late 1950's and early 1960's, the Discoverer/CORONA program made the recovery of film capsules from space nearly routine and achieved numerous technological breakthroughs. In addition to Discoverer XIV, these missions achieving technological breakthroughs included Discoverer I as the first polar orbiting satellite and Discoverer II as the first satellite "to be stabilized in orbit in all three axes, to be maneuvered on command from the earth, to separate a reentry vehicle on command, and to send its reentry vehicle back to earth". Later, the reentry capsule from Discoverer XIII was recovered from the Pacific Ocean to demonstrate the first recovery of a man-made object to be ejected from an orbiting satellite. Finally, Discoverer XIV became the first CORONA mission to be successfully completed and was the first "aerial recovery of an object returned from orbit" as well as the first mission "to return film from orbit. Through these breakthroughs, the CORONA program inaugurated "the age of satellite reconnaissance." Even after the public launches of Discoverer missions ended (after Discoverer XXXVIII in 1962), the covert CORONA efforts continued to support the United States during the Cold War. Ultimately, a total of 145 missions were launched that helped identify Soviet missile launch complexes and the Plesetsk Missile Test Range as well as provided information about what types and numbers of missiles the Soviet Union was developing, testing and fielding (Space and Missile Systems Center). In fact,

the program was so successful that a companion USAF program called SAMOS (Satellite and Missile Observation System) was cancelled in 1962 in large part because CORONA was making it look easy (Wild Black Yonder).

As easy as CORONA made launching satellites and recovering film look, and as successful as history now views the Discoverer/CORONA program, its beginning suffered from demise. In fact, failure was the norm for the first 12 missions. The first launch had to abort because its “upper-stage stabilization rockets fired prematurely.” Every launch between the first one and the successful Discoverer XIII failed. Some failed because the rocket burn times were too short (leading to failure to achieve orbit) or too long (leading to an orbit too high for the use of the camera). Others failed due to film problems (jamming, turning brittle, or turning to powder) (First Military & Spy Satellites, 2005). Others were unsuccessful because the recovery capsule failed (failure of the parachutes to deploy, rockets fired in the wrong direction resulting in going into a higher orbit instead of a reentry orbit, or failing to detach from the spacecraft) (Richelson, 2002). Due to the streak of failures, Richard M. Bissell, Jr., the CIA program manager for the CORONA effort, later commented that it “was a most heartbreaking business. If an airplane goes on a test flight and something malfunctions, the pilot can tell you about the malfunction, and you can look it over and find out. But in the case of a recce [reconnaissance] satellite, you fire the damned thing off and you’ve got some telemetry, and you never get it back. There is no pilot of course, and you’ve got no hardware. You never see it again. You have to infer from telemetry what went wrong. Then you make a fix, and if it fails again, you know you’ve inferred wrong” (Burrows, 1986). After Discoverer XIII was successfully recovered from the ocean (albeit a mission with no camera on-board), the environment of failure was so prominent that Bissell’s assistant, Eugene Kiefer, sent a message saying “Congratulations on a random success” to the USAF officer in charge of procuring the Discoverer/CORONA boosters (Richelson, 2002).

Although it may have started as a failure prone program leading to a “random success,” the Discoverer/CORONA program is a critical achievement in our nation’s history. Not only was it a successful program full of technological “firsts,” but as intended, the CORONA film recovery efforts were able to fill the void of overhead

aerial reconnaissance of the Soviet Union. With the very first film recovery, CORONA began showing there were “far fewer ICBMs [Intercontinental Ballistic Missiles] than the Soviets claimed to have” and President Eisenhower was able to finally get the intelligence data he needed (First Military & Spy Satellites, 2005). As such, Discoverer/CORONA is one space program that many people think of when thinking of a successful space program.

b. Global Positioning System (GPS)

The world’s first navigational satellite system was called Transit and was owned and operated by the U.S. Navy from the first satellite launch in 1960, through the last launch in 1988, and until the program’s cessation in 1996 (Earth Science & Commerce from Space, 2005). Transit, as the world’s first space-based navigation system achieved full operational capability in 1968, just four years after initial operational capability. It “used three operational satellites to produce signals whose Doppler effects and known positions allowed receivers – primarily ships and submarines – to calculate their positions in two dimensions.” This system provided the technological foundation for navigation by satellite and “prepared military users to rely on such a system.” In December 1996, even though several Transit satellites were still fully operational, the constellation was turned off to make room for a “newer, faster, and more accurate system” (SMC History).

That system is the NAVSTAR Global Positioning System or GPS. The GPS program is a joint program primarily lead and managed by the USAF via the Los Angeles based Space and Missile Systems Center (SMC). According to SMC, all of the Department of Defense’s “navigation and position-finding missions are now performed by the Global Positioning System. [GPS] consists of 24 operational satellites that broadcast navigation signals to the earth, a control segment that maintains the accuracy of the signals, and user equipment that receives and processes the signals.” Then-Deputy Secretary of Defense William P. Clements authorized the start of the GPS program in 1973. In the beginning, GPS took advantage of two parallel programs that were on-going in the middle and late 1960’s in the field of space-based navigation. These programs were called 621B and Timation. GPS utilized a combination of these programs using the frequency and signal developments from 621B and the orbital concept for a medium

altitude constellation from Timation. From 1973 to the mid-1990's, GPS followed a traditional acquisition approach. In 1994, the full constellation of 24 satellites was finally on orbit and a full operational capability was announced in April 1995. Since that time, the GPS program has gone through an upgrade effort for GPS-IIR (R stands for "replacement") and the next generation of GPS-III satellites (SMC History).

The GPS program is widely viewed for its military success. According to the National Geographic, "GPS has become the international standard for satellite navigation. It is small wonder that GPS has become the primary operational method for commercial aviation navigation. This revolutionary breakthrough in electronic positioning allows the military to have situational awareness right down to the individual solider and allows the precise navigation of weapons. It allows spacecraft operators to know the precise orbital parameters of their satellites, and it supports an ever growing number of commercial, scientific, and civil users and their applications" (Earth Science & Commerce from Space, 2005).

Perhaps even more than its military success is the tremendous success in the civilian sector that GPS has garnered. As noted above there is an "ever growing number of commercial, scientific, and civil users and their applications." The following essay excerpt shows just how intertwined GPS has become in our every-day civilian lives.

> Back in the car, your cell phone rings and you turn down the radio to hear the message changing your plans. Your cell phone is not in communication directly with a satellite – but the cell tower it connects to relies on precise timing information from the atomic clocks on the U.S. military's Global Positioning System satellites.
>
> As you head to an unfamiliar part of town, it is reassuring to rely on the interactive navigational capability in your car, made possible by the GPS network. Your car's computer uses information from the GPS satellites to triangulate your position, then combines this information with maps in memory, or uses the cell phone network to request directions from an operator. (Christensen, 2005)

As described above, the GPS program is widely viewed as a highly successful application of USAF space expertise. In addition to the wide range of GPS-based civilian uses, GPS' role in precision guided weapons during recent military

operations has added credence to this view. However, as with Discoverer/CORONA, the GPS program is certainly not without its faults. Though the NAVSTAR GPS program was started in the early 1970s, because of USAF funding priorities and other problems, by 1991, there were only 16 of the planned 24 satellites in orbit. The full constellation of 24 satellites and the full operational capability of GPS were not in place until 1994 (Wild Black Yonder, 1998). As recent as the USAF efforts on GPS-III, schedule delays and cost overruns are common-place. According to the Teal Group survey, both GPS IIR-M/IIF and GPS-III are experiencing significant delays and cost growth as a result of "indecision on the part of the Air Force" (Cáceres, 2006).

2. Struggling Programs

The Space Based Infrared System-High (SBIRS-High) and Space Radar (SR) programs are "struggling programs," for various reasons. SBIRS-High was one of the focus programs in the Young Panel. According to the Teal Group's report, SBIRS-High "has experienced the highest cost overruns and the most significant technical problems" of all of the DoD's satellite programs. The Space Radar program is likewise noted in the Teal Group's report as a program at risk due to the history of previous incarnations of the same program being troubled and ultimately cancelled. Furthermore, as will be discussed in the Space Radar section, SR has faced the recent scrutiny of the GAO and Congressional leaders.

a. Space Based Infrared System-High (SBIRS-High)

The Space Based Infrared System-High "is a satellite system intended to provide missile warning information and to support the missile defense, technical intelligence, and battlespace characterization missions. Intended to replace the Defense Support Program, it consists of four satellites (plus one spare) in geosynchronous earth orbit (GEO), two sensors on host satellites in highly elliptical orbit (HEO), and associated fixed and mobile ground stations" (Government Accountability Office [GAO], 2005). In 2003, the GAO investigated SBIRS-High on multiple occasions. As part of the Defense Acquisitions: Assessments of Major Weapon Programs in 2003, the GAO documented significant cost, schedule and technology risks associated with SBIRS-High. In that year, the SBIRS-High program had incurred a Nunn-McCurdy breach (a Congressional infraction of exceeding a cost projection by 25% or more) (GAO, 2003a). Later in 2003,

the GAO concluded the SBIRS-High program still contained critical cost and schedule risks associated with technology development (GAO, 2003b). In the 2005 Assessments of Selected Major Weapon Programs, the GAO documented the SBIRS-High program's second Nunn-McCurdy violation (GAO, 2005). As indicated by the Teal Group's findings from 2005, the projected costs for SBIRS-High have continued to grow by more than 150% – from initial estimates less than $4 billion to current projections between $10-$12 billion – and have resulted in four Nunn-McCurdy violations. Additionally, the original launch date for the first satellite was delayed from 2002 to 2009 (Cáceres, 2006). As of January 2006, SBIRS-High was recognized to still be in serious trouble. At a conference sponsored by the Armed Forces Communications and Electronics Association (AFCEA), the commander of the U.S. Army Space and Missile Defense Command, LtGen Larry J. Dodgen, said "I have severe doubts on whether or not such capabilities" [i.e., SBIRS-High] will exist to support USA requirements and capabilities. According to LtGen Dodgen, the current troubles in USAF space acquisition are having a "negative effect" on Army programs (i.e., the Army Future Combat System) (Tuttle, 2006).

Acknowledging the severe cost and schedule problems that SBIRS-High is dealing with in trying to field this technology, the constellation for SBIRS-High has shrunk from the original plans for five operational GEO satellites and two operational payloads on HEO satellites. Following the last Nunn-McCurdy review, Kenneth Krieg, USecDef(ATL) notified Congress "of the Pentagon's decision to buy no more than three SBIRS-High satellites, with the third to be contingent on the performance of the first" (Singer, 2006). And finally, although the first launch is still three years in the future, the USAF is already investigating plans to fill the shortfall of SBIRS-High with a different "parallel competitor program" called Overhead Non-Imaging Infrared (ONIR) in an effort to "generate competition and exploit new technologies" (Singer, 2006).

As shown here, the SBIRS-High program has a long history of cost overruns. Only the future will show whether or not SBIRS-High has a place in history along side Discoverer/CORONA and GPS as a successful program fraught with challenges or if it will fail to accomplish its stated mission.

b. Space Radar (SR)

In April 1998, the Defense Advanced Research Projects Agency (DARPA), the NRO, and the USAF initiated a joint program called Discoverer II. Discoverer II was intended to provide a 24-satellite constellation of synthetic aperture radar imaging satellites (Discoverer II, 2006). Although initiated in 1998, the Discoverer II program was not new. In fact, it was planned upon the recently “shelved” program called STARLITE. The STARLITE program was cancelled in early 1997 because of redundancies between the USAF and the NRO (STARLITE, 2006). As a result of rising costs – the original projection of $3.5 billion had grown to between $6.5 and $10 billion – and ill-defined requirements, Discoverer II followed in the path of STARLITE and was cancelled by Congress in 2000 (Cáceres, 2006).

In 2001, Space-Based Radar (SBR) was initiated as a new major defense acquisition program. SBR was established as a joint program between the USAF and the NRO with the objective of providing a space borne radar capability for tracking moving targets beginning in 2008 (Space Based Radar History, 2006). Throughout 2004, 2005, and 2006, the SBR program continually faced cost overruns and scrutiny. In 2004, the GAO concluded the SBR would “likely be the most expensive and technically challenging space system ever built by DoD” (GAO, 2004). The GAO also cautioned that the SBR program was repeating many of the same problems previously noted in DoD space programs. These problems include “a failure to match requirements with resources when starting program development” and making commitments to technology prematurely (GAO, 2004). In 2005, the Space Based Radar program was restructured and renamed Space Radar (SR). As of 2005, the constellation of planned operational satellites was reduced to nine, with a first launch projected in “about 2015” at a cost of $34 billion for the total life-cycle costs (Space Based Radar History, 2006).

As briefly discussed, the Space Radar program has a long history of struggling with technology and cost growth. As with SBIRS-High, it is premature to make a final success or non-success decision on this program, and only the future will show whether or not SR has a place in history as a successful program fraught with challenges or if it will fail again as another iteration falling in line with STARLITE and Discoverer II.

E. SUMMARY

The current state of USAF space systems acquisition and engineering culminated, in part from the efforts reviewed in this chapter. As the Teal Group, Young Panel and DAPA Project have noted, the current state of national security space systems acquisition is not where we need to be and is certainly not where we want to be.

Senator Wayne Allard, Republican from Colorado and member of the Senate Appropriations Committee, has been very critical of the current state of national security space acquisitions. At a late 2005 National Defense Industrial Association (NDIA) symposium, Senator Allard voiced his strong feelings on this subject. "As I see it, our nation's dominance in space is being challenged not so much from outside this country but from within. In many respects, we have become our own worst enemy." He continued to state that "Over the last decade, we have done everything possible to sabotage our space supremacy. And, we have done this in every area of government at every possible turn. Our warfighters, program managers, contractors, and yes, even Congress are responsible, and all are guilty of ignoring the warning signs." He clarified his position that it is not the space systems themselves that are creating these problems: "Once it gets to space, our satellites rarely disappoint. Rather, our greatest challenge lies in the development and building of the satellite" (Allard, 2006).

In his NDIA speech, Senator Allard also agreed with most of the conclusions from the Young Panel from 2003 and the fact that these problems still existed in 2005. However, Senator Allard focused on the acquisition process itself, instead of on the lack of talent. He concluded that one of the problems centered on initiating programs prematurely without a thorough understanding of the technology and requirements. Many programs are driven to initiate a program prematurely because it is "easier for a program manager to secure money within the Department by including the technology development and system engineering within an acquisition program." Having so much technology in the core development of an acquisition program leads to "tremendous uncertainty" and forces the schedule of the space program to be "entirely dependent upon how fast the technology can be developed." Furthermore, Senator Allard placed a large amount of blame on the current competitive environment in which a competing contractor must put forth a very aggressive cost proposal. This environment of overly

aggressive cost proposals combined with a lack of experienced program managers and systems engineers means the government will not uncover the “inadequacies of the original baselines” until very late in the program. Finally, Senator Allard stated that there was a “profound absence of discipline when it comes to requirements definition.”

To respond to the current state of national security space acquisition, Senator Allard put forth his own recommendations. Senator Allard’s recommendations include slowing down the newest programs until better trained and more experienced personnel are in place to handle the management and systems engineering of the efforts, creating and justifying realistic cost estimates with a closer review of the required technologies, and limiting the amount of unproven technology and basic research and development that is incorporated into an acquisition program.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. RESEARCH ANALYSIS AND INTERVIEWS

A. INTRODUCTION

The brief survey of successful programs and troubled programs conducted in this research effort reveals some interesting facts. Even the “successful programs” of Discoverer/CORONA and the widely-touted GPS were fraught with acquisition and engineering failures. History has deemed them successful because of the results achieved – in spite of the substantial difficulties in fielding these critical war-fighting capabilities. Perhaps, the same historical success is destined to be true of SBIRS-High and Space Radar.

Furthermore, it is also history that determines success or failure of the various panels and commissions that have convened over the course of the last several decades. Therefore, it is important to view these efforts in relation to the long-term impacts. Table 2 attempts to correlate a snapshot of the most significant recommendations from these panels and commissions as they pertain to the areas of technology, personnel, process, procedures, and organization.

	Packard Commission (1986)	*Acquisition Reform (1990's)*	*Space Commission (2001)*	*Young Panel (2003)*	*DAPA (2005)*	*Senator Allard (2006)*
Technology	Use Technology to Reduce Cost Balance Cost / Performance Expand Use of COTS	Use Technology Insertion Cut Efforts Early if They are Failing Broaden Use of COTS	Advance Technology Leadership	Realistic Budgets / Cost Estimates	80% Performance	Decrease Technology Insertion Realistic Budgets / Cost Estimates
Personnel	Enhance Quality of Personnel	Comprehensive Training Program	Create / Sustain Space Cadre	Train Personnel Accountability	Rebuild and Value Personnel Incentivize Leadership	Get the Right People in Place
Process	Simplify Process Stabilize Programs	Simplify Short, Fixed Price Efforts (to Stabilize)	Shape Legal Environment to Simplify	Numerous Specific Recommendations	Stabilize Stabilize Funding	Simplify and Stabilize
Procedures	Increase Competition	Continuous Competition Implement Commercial Practicies		Limit Competition Use Proven, Best Practices	Risk-based Source Selections (competition)	
Organization	Streamline Organizations		Realign SMC; NRO - USAF Foundation of Space Corps	Numerous Specific Recommendations	Streamline oversight	

Table 2. Recommendation Matrix

As described above, each panel, report, or study entailed many specific recommendations. As seen in Table 2, many of these recommendations actually contradict each other. In fact, the only consistent themes through all of these reports are an emphasis on providing people with the right training and skills and a need to simplify and stabilize the process. Even though the panel and commission recommended an effort to stabilize the acquisition process, they all put forth numerous specific recommendations for changing the process. These contradictions and their lasting impacts on the USAF’s

space systems acquisition and engineering will be analyzed in detail in the remainder of this chapter.

B. RESEARCH FINDINGS

1. Analysis of Differences between Aircraft and Space Systems Engineering

As the Packard Commission accurately depicted in 1986 and the DAPA Project's Executive Summary stated in 2005, the problems of acquisition are to be found all across the Department of Defense. These problems of acquisition are certainly not specific to USAF space systems.

The space environment is not necessarily "harsher," but it is most certainly different. What makes space systems acquisition different is the need to get it done right the first time. As Bissell stated during the days of the CORONA project, once you launch a satellite, you cannot just call it back and evaluate the failure so that you can try again next week (Richelson, 2002). The need to get it done right the first time requires an extra level of program stability and an extra level of expertise and caution.

However, space system acquisition and engineering is not fundamentally different from traditional Earth-bound systems acquisition. Yet, in many cases, it does cost more. The need for exactness and quality drive the cost of satellite systems and is one of the primary reasons why space satellite systems face such scrutiny in the face of cost overruns. An overrun of 50% on a satellite system that started out with a cost of $500M is much more difficult for Congress to accept than a 100% or even a 200% cost growth on a $10M ground transporter. It is ironic that one of the very reasons for keeping space program funding stable (to be able to plan and prepare for an extra level of expertise and caution) is one of the drivers for Congressional oversight and Congressional angst over keeping the funding stable.

2. Research Question Analysis

a. Total System Performance Responsibility

As the 2001 Space Commission, 2003 Young Panel, and 2005 DAPA Project all attest, the idea of TSPR that came out of the 1990's acquisition reform initiatives has largely been discredited. Many failures since the 1990's have been attributed to lack of government participation and oversight during the early stages of the

program. Another aspect of the TSPR era that is not so clearly recognized is a lasting impact on USAF personnel experience. Many individuals in USAF space systems acquisition, through no fault of their own, were "raised" in the acquisition career field under the TSPR era. When this legacy is combined with a lack of systematic and detailed training for personnel in the acquisition and engineering career fields, the DoD is left with an entire generation of acquirers that lack, again through no fault of their own, the requisite expertise to properly do their job.

The recent re-emphasis on systems engineering expertise and training in the years since 2001 (i.e., the Young Panel, the SMC Primer, and the NSSAP 03-01) is an indicator that this TSPR legacy has left a recognized lack of systems engineering expertise, albeit with no quick-fix solution.

b. Drawdown of Systems Engineering Expertise

Another side-effect of TSPR and the acquisition reform era of the 1990's is the inadvertent drawdown of systems engineering expertise on the part of contractors and the DoD and USAF. On the government side of systems acquisition, TSPR called for less technical oversight of the contractors by the government. Concurrently with TSPR (perhaps even a reason for TSPR and acquisition reform in general) was the tightening defense budget in the 1990's. Unfortunately, as the budget got tighter, the contractors had less funding to execute a program. As the government was paying less attention to the systems engineering, the contractors, now without government resistance or scrutiny, curtailed at will their systems engineering effort by cutting their systems engineering personnel. The government's lack of attention to systems engineering inadvertently thus led to a drawdown of systems engineering expertise on the contractor side at the very critical point at which the government was relying on their systems engineering experiese the most. The drawdown of systems engineering expertise on the the government side is recognized as a problem from which the DoD acquisition and engineering force is still recovering. This drawdown recognition is also reflected by the call for greater systems engineering discipline and training in the most recent Congressional panels and studies.

c. Career Progression/Personnel Continuity of Air Force Professionals

The issue of USAF career progression and personnel continuity in systems engineering and acquisition is a key factor in determining the stability for DoD programs and is also closely linked with the training of these USAF personnel. As discussed in Chapter III, many of the studies and reports reviewed in this research recommend various aspects of a remedy for personnel continuity. These recommendations include mandatory four-year assignments for program managers to ensure increased accountability, creation and sustainment of a space cadre with the requisite knowledge to manage and develop systems, and the institution of civilian leadership to foster an environment of reduced personnel transition, among many others. Many recommendations, however, assume that the personnel had the requisite knowledge and experience and that the root problem dealing with personnel stability was too frequent rotations. This assumption may or may not be true. The root problem of the issue of personnel stability may well be the foundational creation of an acquisition and engineering expertise. Once (if) created, these experienced personnel would then be suited for longer duration positions in charge of the systems engineering management and acquisition of critical DoD systems.

d. Use of Federally Funded Research and Development Centers

The use of Federally Funded Research and Development Centers provides the potential for combating the loss of government systems engineering expertise and for increasing the level of continuity between changing government program management. Unfortunately, however, none of the studies investigated in this research emphasized this potential. Greater emphasis on the use of FFRDC may be able to help alleviate the loss of government systems engineering expertise and increase the level of continuity within program management organizations.

3. Other Discoveries Specific to Space Systems Engineering

a. Technology Maturity

Each of the studies and panels investigated in Chapter III discussed technology readiness in some way. The Packard Commission recommended the use of newer technology and commercial-off-the-shelf (COTS) items to help reduce cost and increase performance. Many of the acquisition reform initiatives in the 1990's also recommended the use of technology and expanding the use of COTS to help reduce cost.

Another technology recommendation to come out of the acquisition reform initiatives is the idea of cutting a program early if it is failing. The fact that many efforts of the 1990's are still struggling today (SBIRS-High and SR, to name just two) leads one to believe this recommendation in particular has never been embraced. The recent DAPA Project recommended only pursuing the "80% solution" to achieve a basic capability instead of seeking programs with cutting edge technology to achieve a full desired capability. Additionally, Senator Allard's recommendations included decreasing the reliance on technology. His recommendations suggested technology should be left to be developed in the DoD's set of research laboratories or in using basic research and development funding rather than developing technology as part of a mainstream acquisition program. Senator Allard's recommendation matches well with the 80% solution idea to use what is already available instead of waiting for technology to mature.

As discussed in Chapter III, the level of technological maturity is a key indicator as to how well a program will be executed. The Discoverer/CORONA program was full of new technology and performed many technological 'first' breakthroughs. The first twelve failed launches remain a testament to the difficulty in dealing with these technological breakthroughs. However, the acquisition of Discoverer/CORONA would likely be viewed much differently today. In the 1950's the Discoverer/CORONA program was viewed with the utmost importance and urgency. A program in the 21st century that faces twelve consecutive launch failures would likely not survive long enough to see its place in history turn favorable. This idea of willingness to accept failure when necessity mandates is another key finding of this thesis effort.

b. Risk Acceptance

Perhaps second only to funding stability as an indicator of program performance is the willingness to accept risk. As discussed in the previous section regarding technology, the Discoverer/CORONA program from the 1950's and 1960's is viewed successful historically, but it was fraught with failures in its beginning. Risk acceptance is most fairly viewed as it relates to program urgency. The CORONA intelligence was of the utmost importance then, and the CIA and the Eisenhower administration were therefore willing to accept twelve consecutive failures and to still

attempt the thirteenth launch. The funding was available and the urgent need was real, so the risk was deemed acceptable.

In today's environment of tight budgets, losing a booster can be devastating to a program and can lead to changes in program prioritization and possibly cancellation. At the very least, a failed launch or the failure of a satellite on orbit would lead to months of re-evaluation and examination to ensure the next launch be a success. The level of risk acceptance today is not the same as during the era of Discoverer/CORONA.

c. Funding Stability

Funding stability is of the utmost importance for a program to be a success and is one of the few areas identified as an acquisition problem by the majority of major acquisition studies and reports. Unfortunately, the current budgetary process is driven by a very complex and sometimes inefficient system of checks and balances. Though these checks and balances are necessary to ensure no organization that is a part of the process can abuse its authority, these check and balances lead to an inflexible acquisition system that borders on being impossibly complex. In an acquisition program, the program manager is responsible for the balancing of cost, schedule, and performance/capability (along with many other factors such as risk and political environments). As will be discussed in Chapter IV, the acquisition system is pulled in all three directions of cost, schedule, and performance/capability by the different organizations that are involved. DoD wants the best performance/capability in the shortest amount of time. Congress wants the lowest cost possible so as to be able to fund as many programs as possible. The developing contractor wants to minimize cost and hence to maximize profit and maximize performance as well to remain competitive. Because all three (cost, schedule, and performance/capability) cannot be optimized simultaneously, the yearly budgetary process attempts to fix the yearly cost to be able to solve the conflicting demands of each organization. Unfortunately, fixing the yearly cost without regard for the future cost is very dangerous and leads to programs being extended year by year. This solution also leads to an antagonistic relationship between the DoD, Congress, and the contractors, which creates a spiral of mistrust over the accuracy and accountability of program

projections and program status. Therefore, each year, the funding is in question, and the overall program schedule suffers for it.

d. Personnel Training

Personnel training and expertise is the only area in which all of the referenced studies and Congressional panels consistently agreed. The USAF personnel involved in DoD acquisition must be well trained in order to better produce weapons and equipment for the DoD. The fact that, in early 2006, Senator Allard was still recommending major space programs be delayed in order to wait to get the right people in place to do the job is a testament to the failure of these previous recommendations to have a positive impact on personnel training and expertise. This area of training and expertise holds the greatest potential to make recognizable and lasting contributions to the correction of USAF space systems engineering and acquisition.

The USAF trains a pilot for at least two years and spends hundreds of thousands of dollars (if not millions over the course of a pilot's career) to make sure that each individual pilot knows how to fly his/her specific aircraft. Pilots are drilled with EP's (emergency procedures) to know what to do in the event of any conceivable failure and spend a large proportion of their active duty careers training, upgrading, learning, and re-training. In contrast, at the start of a new career, acquisition professionals get a four-week online course that teaches the fundamentals of acquisition and the timeline of the DoD 5000 series (at a cost of a few hundred dollars.) The curriculum is centered on how to run a program that is already running smoothly, and there is no discussion of how to correct a troubled program (analogous to a pilot's EP's), or even to recognize a troubled program. The extent of instruction on recognizing a troubled program is whether or not it looks like the Powerpoint slide depicting an "on-track" program!

e. Acquisition Process – A System of Checks and Balances

The current Department of Defense acquisition process is highly analogous to the Federal Government's system of checks and balances. The Federal Government was established with an intentional system of checks and balances between the branches of government. The Congress can make laws, but the laws are interpreted by the Judicial arm of the government and the laws are enforced by the Executive office. The Executive branch establishes a budget, but it cannot execute the budget without both

an appropriation and an authorization from Congress. This system of government with each branch having only certain powers is inherently complex and in many ways inefficient. It is also inefficient, helping to ensure no one person or branch of the government would have too much power and influence over the country. So too is the current Department of Defense acquisition process.

A high-level view of the current acquisition process includes the Department of Defense (answering to the Executive office) to establish requirements, the Congress to appropriate and authorize funding, and the industrial complex of defense contractors to execute funding to meet requirements. In this acquisition process, a contractor must compete for a program (thereby wanting to show its proposed cost and schedule in the best possible light.) The DoD establishes requirements knowing that it will take several years to receive a capability (thereby wanting to show a future growth in capability). Finally, the Congress is responsible for establishing appropriation and authorization bills (while trying to fund as many programs as possible for the maximum benefit of the American people and the Congressmen/women's own constituents.) A process set up with such checks and balances is bound to be complex, inflexible, and many times inefficient. Just as the Federal Government's system of checks and balances is not necessarily bad, as it holds each branch responsible for its actions, the DoD acquisition process being set up in a similar fashion is likewise not necessarily bad. Though it may be inefficient, this acquisition process has produced high quality military systems in the past. The fact that the DoD acquisition process is a system of checks and balances holds each organization accountable for its area of responsibility.

C. EXPERT INTERVIEW

1. Donald Hard, Major General, USAF (Retired)

Donald Hard retired from the United States Air Force in August 1993 as a major general. During his distinguished Air Force career MajGen Hard served in a number of space systems acquisition positions that would qualify him as experienced in this field. Since his retirement in 1993, MajGen Hard has served as an independent consultant to various Government organization and aerospace industry companies. He is currently supporting the Air Force Space Command and Space and Missile Systems Center on a variety of space systems engineering efforts. He is also actively supporting numerous

Independent Review Team efforts. Furthermore, he was a member of the Young Panel, convened by USecAF Peter B. Teets in 2003 to review National Security Space programs and processes and is a member of the currently on-going [as of the time this document was released for publication] Independent Senior Advisory Group Space Assessment Team being led by General (USAF, Retired) Larry D. Welch. Additionally, MajGen Hard is currently leading an Independent Review Team in support of the Lockheed Martin Atlas V Program and a collaborative FFRDC review of Space Situational Awareness for the USAF. Finally, he is the principal participant in many on-going reviews of systems engineering in the areas of launch operations and mission assurance for the USAF, the NRO, and NASA.

As noted above, MajGen Hard's decades of active duty experience, consulting experience, and follow-on participation in some of the very panels researched within this thesis qualify him in the fields of space systems acquisition and space systems engineering to provide additional insights on this research topic. The remainder of Section C. describes MajGen Hard's thoughts during a personal interview held on 18 Aug 2006.

MajGen Hard emphasized that systems engineering, though it cannot be divorced from acquisition, is but a part of the systems acquisition process. Therefore, good systems engineers and good systems engineering practices cannot solve today's space systems acquisition issues alone. Additionally, MajGen Hard provided his thoughts on the role of a systems engineer in today's space systems acquisition arena. The acquisition of new space systems has many stakeholders which introduces much instability. In support of systems acquisition, the systems engineer is in the most critical position of risk identification and risk management in support of the program manager. MajGen Hard called budget instability a "fact-of-life" and said the systems engineer must learn to live in this environment and be able to provide the program manager with recommendations for balancing performance/capability and the associated risk within cost and/or schedule constraints. This ability for a systems engineer is especially important in a program that has tight cost, schedule, and performance/capability constraints. In this situation, a program manager may need to accept risk in order to proceed with a program under such tight constraints, and the systems engineer will find

himself or herself in the vital position of determining which risks are acceptable and which ones are not and making a recommendation to the program manager.

The remainder of Section C, Chapter IV, contains thoughts from MajGen Hard pertaining to the author's research findings in Section B of Chapter IV. The author provided his thoughts and research findings to MajGen Hard. The following Subsections a. through j. describe MajGen Hard's supporting thoughts in each of the areas of research findings.

a. Analysis of Differences between Aircraft and Space Systems Engineering

Though it is true that the detailed engineering of a space system is based on the same principles as an aircraft system (e.g., thermal analysis or stress analysis, etc.), the operational environment of a satellite system dictates this detailed engineering be done, in MajGen Hard's words, "absolutely perfectly" prior to launch. The operational environment also requires the space vehicle to be able to survive the launch environment and then to operate for the duration of its mission life autonomously (i.e., without refueling, without hands-on anomaly correction, etc).

Another peculiarity of space systems is the low numbers that are typically purchased. The current USAF budget and acquisition processes are set up to support large quantity buys. Even if one compares a low-quantity buy aircraft (F/A-22) and a high-quantity-buy satellite system (GPS), the difference in production units is a full order of magnitude. As MajGen Hard stated this issue, "Equally important, in a space system acquisition, changes in the current year development costs cannot be easily mitigated by simply changing the number of units to be produced." More specifically, this means any cost impacts on a satellite acquisition system will need to be absorbed by a smaller production run and the associated per-unit cost will be inflated by a much higher percentage.

Finally, the fact that a satellite system must be launched before use is another critical difference. Launching satellites into space is not routine; in fact, it is often the harshest environment the satellite will face. In addition to a satellite needing to meet derived requirements for survivability during launch, the launch itself is the most dangerous prospect in the satellite's life. Boosters can fail or insert a satellite into the

incorrect orbit. Because launch is still an inherently dangerous prospect for a satellite to survive, there is a natural tendency for engineers and program managers to "get-the-most-bang-for-the-buck" and put as many payloads and as much capability onto a space platform as possible. Combining different payloads on a single satellite has many disadvantages. As MajGen Hard stated, this leads to "complex arrangements all through a program's life cycle – from requirements generation through prioritization during operations." This natural tendency is contrary to the way early aircraft systems were produced and is contrary to long-term desires to make space use routine and operationally responsive. Coupled with the low-quantity buys of space systems, this tendency also further exacerbates the cost, schedule and performance/capability problems that are seemingly inherent in space systems development.

b. Total System Performance Responsibility

Based on his previous consulting efforts, MajGen Hard agreed there is a lasting impact of the TSPR reform initiatives on today's USAF systems engineering expertise. Describing first-hand experience, he described an era of declining defense budgets leading to personnel cuts and a drawdown in active duty and government civilian systems engineering expertise in the early 1990's. At the time, TSPR was an imposed shift in systems acquisition. The FFRDC were capped and could not provide the required experts to fill the void. Furthermore, second source developers and Systems Engineering and Technical Assistance (SETA) contractors could not be brought on board to support due to unqualified personnel and the declining budgets. In large part, this lack of government systems engineers led to the TSPR idea of requiring the prime developing contractors to conduct the necessary systems engineering. Over time, the government systems engineers who should have been managing risk in light of the declining budgets became reporters. In addition to creating a passive cadre of government systems engineers, the TSPR initiatives contributed to a "we vs. they" mentality between the government and the contractor communities. This mentality will be discussed later under Subsection h in Section C.

c. Drawdown of Systems Engineering Expertise

As described by MajGen Hard, during the interview, the TSPR initiative combined with tighter budgets, inevitably led to "out-of-control advocacy," incredibly

low cost estimates and the unfortunate consequence of a parallel drawdown of systems engineering expertise on the contractor side of the "we vs. they" paradigm. In a program with a dwindling budget, due to the lack of specific government oversight, an easy place for a contractor to cut costs is in management and systems engineering. After all, it is nearly impossible to cut costs once a program has "bent metal." At this point, late in a program, the manufacturing and build costs have already been determined as a result of decisions made much earlier in the program. However, it is still relatively easy ("although usually disastrous") to cut the labor hours of the management staff and the systems engineering staff. This drawdown in contractor systems engineers, combined with a now passive government systems engineering management approach, deferred the looming risk until later and further exacerbated the acquisition process.

d. Career Progression/Personnel Continuity of Air Force Professionals

MajGen Hard agreed there are issues related to continuity of USAF personnel. He viewed these issues as being related to training issues and his thoughts will be discussed and included later in Subsection i in Section C.

e. Use of Federally Funded Research and Development Centers

As noted above in his discussion of TSPR, MajGen Hard explained the use of FFRDC as his preferred approach to filling the void in government expertise. Unfortunately, the use of this critical resource is capped by Congress, and there simply isn't enough to meet the need.

f. Technology Maturity

In the area of technological maturity, MajGen Hard echoed and wholeheartedly agreed with the 80% solution idea discussed earlier in Section B. He also agreed with an incremental block-building approach to developing and producing space satellite systems. Additionally, as noted above, MajGen Hard described the natural tendency to fill a satellite with as much capability as possible. This natural tendency pushes the state-of-the-art of technology and significantly increases risk. Therefore, in MajGen Hard's words, the development of high technology space systems is "naturally expensive" and "naturally prone to risk." Also, according to MajGen Hard, "today's systems are much more complex than when the text books were written" making the acquisition of these systems that much more difficult.

Another factor leading to a satellite system's complexity is the difference between developing what MajGen Hard called a "first-of" capability as opposed to a replacement system. As the USAF began developing satellite systems, such as CORONA, DSP, and DSCS, each minor success was hard-fought and the entire program was done by virtue of investments for general capabilities (photographic reconnaissance, early warning, and strategic communications respectively). These programs were all "first-of" capabilities. Today, while attempting to replace capabilities that have become critical to our national security, the DoD wants an improved capability that still operates with the legacy system it is replacing and that is specified "to the third decimal point" right off the launch pad and will accept little else. In this situation, motivation to improve is "the enemy of good-enough." This motivation to improve further drives technology development which, in a program of fixed cost and fixed schedule, creates an extremely risky program.

g. Risk Acceptance

MajGen Hard viewed the systems engineer's role as critical to study the risks and study the program to know which risks are acceptable. The systems engineer's role is central to the trade of cost and/or schedule and/or performance/capability with risk. This role also must assist the program manager make trades between risk and urgency of a program. If the cost and schedule profiles are determined to be fixed, MajGen Hard asserted risk acceptance is sometimes the only way to balance the cost, schedule, and performance/capability pressures of an acquisition program. Therefore, the systems engineer's job in risk identification and risk assessment is of the utmost importance.

h. Funding Stability

"Learn to live with budget instability." According to MajGen Hard, budget, and therefore program, instability has become a fact of acquisition and the program manager and systems engineers must learn to live with this instability. In part, this is because one of the real problems of acquisition in general is the need to form program advocacy in order to support the Congressional budgeting process. There are so many stakeholders involved in the process that budget stability is an impossibility because of the stakeholders' competing interests. Furthermore, each of the organizations

involved can stop an effort or impact an effort, but it takes the willing and able cooperation of all organizations simultaneously to form progress. For space satellite programs, this instability is compounded by a mismatch within the USAF budgeting process between mainstream high-production quantity aircraft programs and low-production quantity satellites systems. The lead systems engineer must be able and willing to analyze trades of schedule and performance/capability with acceptable risks to make good recommendations in order to match the ups and downs of budget instability. Therefore, the systems engineer's job becomes again, one of risk identification, risk assessment, and risk mitigation. Risk management is his or her primary role in USAF space systems engineering.

Additionally, budget instability drives, and is driven by, the lasting "we vs. they" relationship between developing contractors and the government program offices that resulted from the implementation of TSPR and underfunded contracts. Because, as MajGen Hard stated, the "contractor is working on a 'cut-my-losses' basis [due to the severe cost competition environment], the government program office no longer trusts the contractor cost estimates." Neither does the Congress trust the government program office cost estimates. There is mistrust among all stakeholders in the budget process and, almost inevitably, a program will not be funded for success, or even the most probable cost, but rather, will be funded based on an unrealistic or unreasonable cost estimate that could be justified as the bare minimum acceptable.

Finally, MajGen Hard warned against too much stability in the acquisition process that could lead to a stagnant acquisition process. Though he agreed change for the sake of change is unnecessary and can be dangerous, he cautioned that complete process stability can be a sign that "something is dying." Within all processes, there should be room for continuous improvement and one job of a systems engineer is to help the program manager analyze risks and accommodate necessary change, e.g., Continuous Process Improvement, in the most cost effective way possible.

i. Personnel Training

Although MajGen Hard agreed that personnel training is necessary and good for a systems engineer, he disagreed with the ability or even recommendation to prescribe a single process for training all acquisition and engineering officers that will

enter the Space Cadre. He recalled his own on the job training and early experiences in developing space programs. Primarily, his training was a result of listening and learning as a young officer. His supervisors took it upon themselves to work with him on a daily basis and tell him what to do, show him how to do it, and within that, how to interact, in a team environment, with the developing contractors. MajGen Hard noted this type of training and education is unlikely to be possible today. Partially as a result of TSPR and the we/they-relationship between contractors and government (due to the "bet-your-company cost-plus competitions), and primarily a result of manning shortfalls, most supervisors today simply do not have the time to take the same care and effort in training young officers as MajGen Hard related from his early experiences. In his first experience, he was a lone lieutenant in a large office full of experienced and qualified majors and lieutenant colonels who all helped "raise him" in acquisitions.

Based on his previous consulting efforts, MajGen Hard stated a typical space program office today is minimally manned at 65% of the allowed personnel due to manning shortfalls. Additionally, in a typical space program office today, the relative ratio of junior to senior officers is reversed from MajGen Hard's days when there were far fewer junior officers. Because the new accessions are struggling to learn their role as an engineer or acquisition officer, the small number of well qualified senior individuals are forced to do much more of the burden of work leaving less and less time for instructing or mentoring the next generation of space systems engineers.

Instead of a concentrated, standard training effort, MajGen Hard recommended an approach of pulling space systems engineers from the full range of related activities: laboratories, operational assignments, other acquisitions, and brand-new accessions. The important thing he felt is a trait that cannot be trained no matter what formal or long-term training is implemented: Passion. Based on MajGen Hard's independent review efforts, he stated the success of many satellite programs in the past has been, in large part, a result of passionate people working hard for things they believe in. Relating to the passion of individual program managers and systems engineers working in a complex acquisition process, MajGen Hard said "sometimes, we [the USAF] have been successful in spite of the process." Unfortunately, in an office where lieutenants are struggling to learn their job and their supervisors have little time to assist

them, the environment is not conducive to fostering this type of personal passion for the mission or the job.

j. Acquisition Process – A System of Checks and Balances

MajGen Hard agreed with the fundamental idea that the system acquisition process is inherently difficult. He used the terminology of the DAPA Project that the Big-A (Acquisition Process) is a precarious balance of the budget, requirements, and acquisition processes. The Little-A is the "how-to" acquisition process that describes the day-to-day management activities of a program office. As the DAPA Project stated, MajGen Hard agreed that the Big-A is a highly complex and interdependent process and systems engineering is just one piece of the Little-A. Yet, good systems engineers, with a passion for what they do and a supportive environment, have the ability to properly assess and help manage the risks that are driven by the Big-A acquisition process.

Additionally, MajGen Hard reiterated one possible way of attempting to address this complexity inherent in the acquisition process would be in splitting the space budget from the USAF budget as a stand-along Major Force Program (MFP). This recommendation was in the Space Commission report in 2001 and would help alleviate the issues of space programs competing with other USAF programs for funding and advocacy.

D. SUMMARY

Many of the research findings discussed above are not new. In fact, several of them have been repeatedly put forth by many of the Congressional panels and commissions that have reviewed the status and well-being of space systems acquisition specifically as well as defense systems acquisition in general. As shown in this Chapter, this acquisition process is an inherently difficult process – not just because it is a difficult endeavor to balance the competing forces of cost, schedule, and performance/capability within constrained resources of people, funding, time, etc., but also because it is difficult to operate in, through, and from the space environment. Partially as a result of these efforts, including the Packard Commission, Acquisition Reform Initiatives, the Space Commission, and the Young Panel, the current status of USAF space systems acquisition is both as good and as bad as described in this thesis. However, if the USAF is to overcome the recent spate of admonishment from Congress and others that it has faced,

much work remains. Unfortunately, as described previously in Chapter IV, many of the very same panels and commissions that have admonished the process have also provided conflicting recommendations for resolving the issues associated with defense systems acquisition. According to the analysis in Chapter III, one area that holds the most significant promise for being able to realize focused, incremental improvements is systems engineering – specifically the level of expertise for USAF systems engineering personnel. The recommendations provided by the author in Chapter V are intended to echo some previous and still-valid recommendations from the various commissions reviewed and also are intended to provide a focus on the role and responsibility of the USAF systems engineer to assist the program manager balance the difficult task of developing and delivering space systems for the Department of Defense. These recommendations are based upon the in-depth literature review and the discussion with MajGen Hard of the author's research findings documented in Chapter IV.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS AND RECOMMENDATIONS

A. OVERVIEW OF SPACE SYSTEMS ENGINEERING AND ACQUISITION

The following 20-year synopsis of DoD acquisition and space systems engineering shows how significant the problems pertaining to space systems acquisition are:

> In 1986, the Packard Commission said "… when a program finally receives budget approval, it embodies not only overstated requirements, but also underestimated costs."
>
> In 2001, the Space Commission stated "The U.S. will not remain the world's leading space-faring nation by relying on yesterday's technology to meet today's requirements at tomorrow's prices."
>
> In 2003, the Young Panel concluded "Significant cost growth and schedule delays in many critical space system programs have caused senior DoD and Intelligence Community leadership to question our nation's ability to acquire and sustain national security space systems."
>
> In 2005, in response to the question "Whether or not cost overruns are inherent in U.S. military satellites under development," the Teal Group responded, "we cannot say for sure. We can say that these overruns seem to be endemic."
>
> Also in 2005, the DAPA Project stated "Congress and Department of Defense senior leadership have lost confidence in the Acquisition System's ability to determine what needs to be procured or to predict with any degree of accuracy what things will cost, when they will be delivered, or how they will perform."
>
> In 2006, Senator Allard, member of the Senate Appropriations Committee, said "Over the last decade, we have done everything possible to sabotage our space supremacy. And, we have done this in every area of

government at every possible turn. …[O]ur greatest challenge lies in the development and building of the satellite.”

The problems today are no less severe than 20 years ago. If anything, the problems today are more significant because many of the space systems developed and deployed in past decades during an era of larger budgets and greater forgiveness of risk are now aging and in need of replenishment and/or replacement. The fact that the DoD space systems engineering and acquisition processes have been as successful as they have is a strong indicator of the determination, expertise, and passion of the personnel involved. This fact is also, ironically, a reason for high expectations today, in an era of tighter budgets and less tolerance of high risk – high failure programs. As space becomes “routine” and commercial launch providers establish a successful track record of access to space, this expectation will become higher and higher of military space professionals. These space professionals – primarily in the USAF – must be properly trained and equipped to handle the job that will be expected of them.

B. SPECIFIC RECOMMENDATIONS

Although each finding above is not necessarily conducive to a specific, actionable recommendation directly pertaining to space systems engineering expertise, the following ideas are recommended for consideration based on the research conducted.

1. Analysis of Differences between Aircraft and Space Systems Engineering

As discussed in Sections B. 1 and C. 1. i of Chapter IV, space systems – specifically the satellite components of space systems – must be absolutely perfect prior to launch. Additionally, the launch environment itself is still a dangerous and non-routine activity that must be overcome for a satellite system to be successful. Therefore, there is a natural tendency for program managers and systems engineers to want to include as many payloads and as much capability in a satellite system as possible prior to launch. Finally, because space systems are typically more expensive than traditional earth-bound systems due to the reasons outlined in Sections B. 1 and C. 1. i of Chapter IV, program advocacy, in MajGen Hard’s words, is “out of control.” Based on this analysis, the following recommendation is put forth:

- Embrace and develop routine access to space with an enhanced launch infrastructure.

This recommendation would allow space systems to be more feasibly launched in incremental fashion because the lower resulting cost associated with launch would result in less desire to get the “bang-for-the-buck” by striving for 100% capability and multiple payloads. Although costly in the near-term, following this recommendation could also, over time, establish a more cost-effective launch infrastructure to support future space programs.

2. Total System Performance Responsibility

Since the 1990’s implementation of TSPR as an acquisition reform policy, nearly every other major review of DoD systems acquisition has concluded that TSPR has created more problems than it solved (including the Young Panel, specifically responsible for a review of space systems engineering and acquisition). As such and as shown in Sections B. 2. a and C. 1. b of Chapter IV, many USAF systems engineers today do not know their role in the acquisition process. This role is one of risk management. The following recommendation will help define and determine the future role of USAF systems engineers in the systems acquisition process.

- Define the role of the government systems engineer as one of a risk manager – utilize systems engineers to identify, assess, and mitigate program cost, schedule, and performance/capability risks.

The government systems engineer’s fundamental role is to identify, assess, and mitigate risk in support of the program manager. Rather than being a reporter, properly trained government systems engineers may effectively be able to help erase the remaining legacy of TSPR and help maintain stability in the acquisition cycle by conducting quality risk management.

3. Drawdown of Systems Engineering Expertise

As shown in Sections B. 2. a/b and C. 1. b/c of Chapter IV, the drawdown of systems engineering expertise on the part of the contractors and DoD/USAF is closely related to the TSPR reform initiatives of the 1990’s. Therefore, the same recommendation applies:

- Define the role of the government systems engineer as one of a risk manager – utilize systems engineers to identify, assess, and mitigate program cost, schedule, and performance/capability risks.

In addition to being closely linked with TSPR, the recommendations from the following Sections 4 and 5 may also help alleviate the residual drawdown of systems engineering expertise.

4. Career Progression/Personnel Continuity of Air Force Professionals

As discussed in sections B. 2. c and C. 1. d of Chapter IV, career progression and personnel continuity of USAF professionals create many issues for space systems engineering. As personnel move from one job to another, it is necessary to have a method of tracking the top-performers who show the greatest ability to conduct systems engineering and systems acquisition.

- Implement a method of tracking the top space acquisition and space engineering professionals.

In addition to the Air Force Space Command's recent efforts at creating a professional Space Cadre, the method recommended by then-Major Christopher Forseth in "The Pursuit of Acquisition Intrapreneurs" of tracking top performing acquisition professionals could help reverse the lasting TSPR impact of creating a passive government cadre of systems engineers.

5. Use of Federally Funded Research and Development Centers

As discussed in Sections B. 2. a/b and C 1. b/c, there are not enough government and contractor systems engineering personnel to properly conduct systems engineering activities in support of space systems acquisition. Additionally, Sections B. 2. d and C. 1. e of Chapter IV discussed a shortage of FFRDC personnel to meet the need for systems engineering expertise. Therefore, the number of FFRDC should be reviewed.

- Establish and conduct a review of numerical sufficiency of FFRDC to meet the needs of USAF space systems acquisition.

As noted by MajGen Hard, one of the key drivers for the institution of TSPR reform policies was a lack of sufficient FFRDC personnel to fill the void of government systems engineering expertise. In part, this was and remains dependent on

Congressionally mandated personnel restrictions. In an effort to help the government meet the requirement for greater systems engineering expertise while its own personnel become better equipped to properly conduct systems engineering activities, the current caps on numbers of FFRDC personnel should be reviewed for sufficiency in light of the number and complexity of on-going and near-term space programs.

6. Technology Maturity

Technology maturity has repeatedly been an issue for space systems engineering. This was discussed in the findings of the Young Panel, the DAPA Project, the Teal Group and most recently by Senator Allard. The following recommendations are re-iterated from these previous studies.

- Institute detailed technology review as part of all Milestone Decisions.
- Embrace 80% solution methodology recommended by numerous panels.

Neither of these recommendations is new or original. However, it is hoped that these recommendations will find better traction for acceptance in the future if a more cost-effective launch infrastructure is put in place as recommended in Section B. 1 of this chapter.

7. Risk Acceptance

Some risk is unavoidable. If a program is urgent and has acceptable risks, the program should be funded appropriately. As discussed above in Sections B. 3. b and C. 1. g of Chapter IV, some programs contain risk associated with program urgency and some programs contain risk associated with trades of cost and/or schedule and/or performance/capability. The following recommendation is provided, assuming a systems engineer has identified and assessed the risk as recommended in Sections 2 and 3 of this chapter.

- Fund programs appropriately and recognize the risk associated with the funding level.

This recommendation assumes a systems engineer is provided the skills and authority to complete his/her job as the risk manager of a program. This recommendation specifically does not recommend planning for a high-technology breakthrough as the solution; rather it depends on the systems engineer to identify and assess the risk, create a

mitigation strategy, and then make recommendations to the program manager who can request funding as required. If the funding requested is not available, the systems engineer is responsible for either recommending cuts to performance/capability to maintain a proper cost, schedule, and performance/capability balance or recommending what new risk to accept under what new risk mitigation strategy.

8. Funding Stability

As recommended by the Space Commission Report in 2001, the establishment of a Space Major Force Program would help bring about greater funding stability for space programs. The establishment of a Space MFP would effectively further the Space Commission recommendation for laying the foundation of an eventual Space Corps or Space Force. Based on the ideas in Sections B. 3. c and C. 1. i of Chapter IV, and the fact that the Space Commission Report's recommendation has not yet been adopted, the following recommendation is made:

- Establish a Space Major Force Program as originally recommended in the 2001 Space Commission Report.

This recommendation is not new or original. However, as noted in "A Separate Space Force: An 80-Year-Old Argument," by Chaplain Colonel Michael C. Whittington in 2000, funding is one of the key reasons the USAF fought for independence from the United States Army. It is also one of the key reasons the USAF ought to consider and embrace an independent Space Corps to prevent funding conflicts between the USAF's top priority programs (e.g., F/A-22) and the United States' national security need for space systems. It is hoped that this recommendation will find better traction for acceptance in the future in light of tighter budgets and the growing complexity and cost of both space satellite systems and traditional aircraft systems.

9. Personnel Training

The lack of detailed training for systems engineering personnel in the USAF is closely linked with the career progression/personnel continuity issues discussed previously under Section B. 4 of this chapter. The same recommendation applies.

- Implement a method of tracking the top space acquisition and space engineering professionals.

In addition to this repeated recommendation, two other recommendations also apply based on the research included in Sections B. 3. d and C. 1. i of Chapter IV.

- Implement and conduct basic space systems engineering training in support of space systems acquisition.

Based on the findings in Section B. 3. d of Chapter IV, there would certainly be some value added in conducting some basic training for all space systems acquisition personnel – specifically the systems engineering personnel. Although MajGen Hard offered caution before implementing a full structured and detailed training program, as this recommendation states, a basic space systems engineering training program should be analyzed in greater detail for implementation.

- Reward mid-level supervisors for good performance by their subordinates.

Provided these mid-level supervisors have been recognized and tracked according to the recommendation in Section B. 4, this recommendation would foster an environment for mentoring and learning the systems engineering trade by virtue of leading by example. Mentoring need not be contrived and is best done by listening and learning naturally.

10. Acquisition Process – A System of Checks and Balances

Based on the analysis described in Sections B. 3. e. and C. 1. j of Chapter IV, the acquisition process itself is inherently difficult. Pronounced by the Packard Commission and recently by Senator Allard, this fact regarding the acquisition process is readily apparent. Rather than allowing the process by which space systems are developed to become the most significant burden, the following ideas are recommended for consideration:

- Maintain stability of the "Little-A" (as defined by the DAPA Project) by not instituting sweeping, divergent change every time a program faces adversity, but do not stifle creativity and passion.

This recommendation would allow a systems engineer the opportunity to properly conduct his/her most important job – risk management, including risk identification, assessment, and mitigation.

- Identify, assess, and mitigate risk to accommodate changes in the "Big-A" acquisition process.

Fulfilling this recommendation constitutes a systems engineer's real opportunity to help a flailing space systems acquisition process improve. By identifying, assessing, and mitigating risks, a properly trained and equipped systems engineer could effectively assist the program manager lead a program to success in spite of an inefficient and flawed acquisition process.

C. SUGGESTED AREAS FOR FUTURE STUDY

This has been a massive undertaking – much larger than this researcher anticipated at the start of this project – and many stones remain unturned. Much work remains to be accomplished. It is the hope of this author that the historical overview and analysis of previous studies accomplished in this thesis will provide a foundation, or at least a stepping stone, for future researchers to expand upon these recommendations and steadily make progressive improvements in DoD and USAF space systems engineering expertise.

Between the time of the Young Panel and the DAPA Project, Air Force Space Command and the Space and Missile Systems Center have made great strides toward improving the Space Cadre recommended in the Space Commission. These efforts were commended in the Young Panel, and for what it is worth, this author offers his commendation as well. These efforts promise to bear significant fruit in expanding the expertise of USAF Space Professionals and USAF space acquisition experts. However, as noted above, these individuals must be tracked and allowed to "grow-up" in their respective space career fields. Training a junior engineer in one of the new space professional education courses does little good for the future of space systems engineering if her next job is in Air Force Materiel Command working on an F/A-22 upgrade. Further analysis is needed to delve into the tracking of space professionals and how to let them prosper as Space Cadre without impacting their competitiveness for promotion as compared to rated officers and traditional acquisition/engineer officers.

Tracking space professionals is important, but more emphasis should also be placed on properly tracking acquisition professionals in general. This tracking should

include engineers and scientists as well as acquisition officers. The implementation of detailed, albeit time consuming, training has been recommended above for new engineers and acquisition officers. As recommended by Lt Col Forseth in "The Pursuit of Acquisition Intrapreneurs," (2001) a rewards structure including the long-term designation as an 'expert' should be further analyzed for possible implementation as soon as possible.

In conjunction with the tracking of a Space Cadre, further research is required as to the potential benefits of establishing a separate space budget distinct from the USAF budget. The Space Commission recommended the foundation be put in place for the eventual implementation of a Space Corps or Space Force. Efforts to establish a single chain of command under Air Force Space Command have begun to prepare the USAF for such a change. However, the USAF budget still contains competition between space programs (e.g., SBIRS-High) and mainstream USAF programs (e.g., F/A-22). In addition to furthering the Space Commission's recommendations, creating a Space Major Force Program would induce greater funding and program stability in space programs. This recommendation should be analyzed in greater detail for implementation as soon as possible.

Finally, the issue of FFRDC utilization is another area that requires further study. The issues associated with a lack of government systems engineering expertise are not going to be resolved quickly by implementing any or even all of the recommendations put forth in this thesis or any other study to date. The FFRDC's role in space systems engineering can hold promise to help fill this void if utilized effectively. Unfortunately, limited by Congressional caps, the current level of support the FFRDCs are able to provide is less than is required. This limitation should be investigated and a determination made whether or not the level of available FFRDC support can be increased quickly enough to support the government in the near term.

D. SUMMARY

The government systems engineer's fundamental role is best defined as a risk manager in support of the program manager. In addition to the basic systems engineering skills discussed in Chapter II, the additional ability to identify, assess, and mitigate risk comprises a good systems engineer's real opportunity to help a flailing space system

improve or help a new space system avoid unnecessary cost, schedule, or performance/capability impacts. A properly trained and equipped systems engineer can effectively assist the program manager lead a program to success in spite of an inefficient and flawed acquisition process.

The two primary themes that each major panel or commission to study Defense Department acquisition has had in common are training people and simplifying the budgetary process. The Packard Commission, in the mid-1980's stated that the greatest chance for fundamental improvement in the performance of defense acquisition was a fundamental change in the budgetary process. Even within the existing budgetary process and the "Big-A" as defined by the DAPA Project, a well equipped cadre of systems engineering professionals can effectively support the program managers in making incremental improvements in the cost and schedule performance or our nation's most critical national security space systems.

LIST OF REFERENCES

Allard, Wayne, Senator. (2005). National Defense Industrial Association conference speech. Retrieved 23 September 2005 from http://allard.senate.gov/public/index .cfm?FuseAction=Legislation.ViewIssue&IssuePosition_id=1601&IsTextOnly=1.

Ancona, Deborah, Kochan, Thomas A., Scully, Maureen, Van Maanen, John, & Westney, D. Eleanor. (2005). *Managing for the Future. Organizational Behavior & Processes.* (3rd ed.). Mason, OH: South-Western.

Assessment Panel of the Defense Acquisition Performance Assessment Project. (2005). "Defense Acquisition Performance Assessment Executive Summary."

Blue Ribbon Commission on Defense Management. (1986). "A Formula for Action: A Report to the President on Defense Acquisition."

Burrows, William E. (1986). *Deep Black: Space Espionage and National Security.* New York, NY: Random House.

Cáceres, Marcus. (2006). Cost overruns plague military satellite programs. *Aerospace America,* 18 – 20, 23.

Chairman of the Joint Chiefs of Staff. (2005). CJCSI 3170.01E, "Joint Capabilities Integration and Development System."

Christensen, Carissa Bryce. (2005). Life With Satellites. In L. K. Glover (Ed.), *National Geographic Encyclopedia of Space* (pp. 312-313). Washington D.C.: National Geographic.

Commission to Assess United States National Security Space Management and Organization. (2001).

Defense Acquisition University. (2004). "Joint Program Management Handbook."

Defense Acquisition University. (2001). "Systems Engineering Fundamentals."

Defense Science Board. (1993). Report of the Defense Science Board Task Force on Defense Acquisition Reform.

Defense Science Board. (1994). Report of the Defense Science Board Task Force on Defense Acquisition Reform (Phase II).

Defense Science Board. (1996). Report of the Defense Science Board Task Force on Defense Acquisition Reform (Phase III).

Defense Science Board. (1999). Report of the Defense Science Board Task Force on Defense Acquisition Reform (Phase IV).

Defense Science Board. (2003). Report on Acquisition of National Security Space Systems.

Department of Defense. (2003). Department of Defense Directive 5000.1, "The Defense Acquisition System."

Department of Defense. (2003). Department of Defense Instruction 5000.2, "Operation of the Defense Acquisition System."

Department of Defense. (2004). National Security Space Acquisition Policy 03-01, "Guidance for DoD Space System Acquisition Process."

Department of the Air Force. (1991). MIL-STD-1809, "Space Environment for USAF Space Vehicles."

Discoverer II (DII). (2006). *GlobalSecurity.org.* Retrieved 22 August 2006, from http://www.globalsecurity.org/space/systems/discoverer2.htm.

Earth Science & Commerce from Space. (2005). *National Geographic Encyclopedia of Space* (pp. 315-318). Washington, D.C.: National Geographic.

First Military & Spy Satellites. (2005). *National Geographic Encyclopedia of Space* (pp. 335-338). Washington, D.C.: National Geographic.

Forsberg, Kevin PhD, Mooz, Hal, and Cotterman, Howard. (2000). Visualizing Project Management: A Model for Business and Technical Success.

Forseth, Christopher, Lieutenant Colonel (then-Major), USAF. (2001). *The Pursuit of Acquisition Intrapreneurs*.

Government Accountability Office. (2003). *Defense Acquisitions: Assessments of Major Weapon Programs.* (GAO-03-476). Washington, DC.

Government Accountability Office. (2003). *Defense Acquisitions: Despite Restructuring, SBIRS High Program Remains at Risk of Cost and Schedule Overruns.* (GAO-04-48). Washington, DC.

Government Accountability Office. (2004). *Defense Acquisitions: Space-Based Radar Effort Needs Additional Knowledge Before Starting Development*. (GAO-04-759). Washington, DC.

Government Accountability Office. (2005). *Defense Acquisitions: Assessments of Selected Major Weapon Programs*. (GAO-05-301). Washington, DC.

Lord, Lance, General (Retired), USAF. (2005). People, Process and Partnerships… Our Keys to Acquisition Success! *High Frontier*. 2 – 3.

National Aeronautics and Space Administration. (1995). SP-610S, "System Engineering Handbook."

Rechtin, Eberhardt. (2000). Retrieved 27 February 2006, from www.incose.org/practice/ fellowsconsensus.aspx.

Richelson, Jeffrey T. (2002). *The Wizards of Langley: Inside the CIA's Directorate of Science and Technology*. Boulder, CO: Westview Press.

Sheard, Sarah. (2000). "Systems Engineering Roles Revisited." Software Productivity Consortium.

Singer, Jeremy. (2006). *Pentagon Scales Back SBIRS Program*. C4ISR: The Journal of Net-Centric Warfare.

Space and Missile Systems Center. "Historical Overview of the Space and Missile Systems Center." Retrieved from http://www.losangeles.af.mil/SMC/HO/ INDEX.HTM.

Space and Missile Systems Center. (2005). "SMC Systems Engineering Primer & Handbook."

Space Based Radar History. (2006). *GlobalSecurity.org.* Retrieved 22 August 2006, from http://www.globalsecurity.org/space/systems/sbr-history.htm

STARLITE. (2006). *GlobalSecurity.org.* Retrieved 22 August 2006, from http://www.globalsecurity.org/space/systems/starlight.htm.

Tuttle, Rich (2006). *LtGen.: AF Space Program Woes Hurting Army Capabilities*. Aerospace Daily & Defense Report.

Whittington, Michael C., Chaplain, Colonel, USAF. (2000). "A Separate Space Force: An 80-Year-Old Argument." Air War College, Air University.

Wild Black Yonder. (1998). *American Eagles: A History of the United States Air Force* (pp. 408-409). Charlottesville, VA: Howell Press.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Dr. Thomas Huynh
   Naval Postgraduate School
   Monterey, California

4. Lieutenant Colonel Christopher Forseth
   Commander, Space Superiority Rapid Reaction Squadron
   Peterson Air Force Base, Colorado

5. Mr. Thomas Fitzgerald
   SMC/AX
   Los Angeles Air Force Base, California

6. Colonel Michael Taylor
   Commander, Space Superiority Systems Wing
   Los Angeles Air Force Base, California

7. Mr. Donald Hard
   MITRE Corporation
   El Segundo, California

8. Dr. Rudolf Panholzer
   Chair, Space Systems Academic Group
   Naval Postgraduate School
   Monterey, California

9. Mr. James Green
   Acquisition Chair
   Naval Postgraduate School
   Monterey, California

10. Mr. Robert Beck
    Dean, Graduate School of Business and Public Policy
    Naval Postgraduate School
    Monterey, California